High-Efficiency Inverted Instruction: Doubling Capacity while Preserving Small Classroom Quality

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Abstract

The inverted or "flipped" classroom model of teaching is growing in popularity and used in both K-12 classrooms and higher institutes of learning across many disciplines. Published benefits of this model include higher student engagement, increased peer learning, lowered student frustration, and the ability of the instructor to provide immediate, direct feedback to students. However, this model requires a substantial investment of time from the instructor to properly prepare and distribute material that would have been covered in a traditional lecture. At the same time, there is substantial pressure on universities to lower tuition costs and use more efficient models of teaching such as MOOCs. In this paper we discuss a model for flipping classrooms that quickly amortizes the initial instructor investment and addresses the university need to reduce costs. At Cal Poly, San Luis Obispo, we converted one of our highly impacted core programming courses, CPE 357 Systems Programming, to an inverted style of instruction that greatly increased instructional throughput without significantly increasing instructional costs. Under our high-efficiency model, we can minimally double the sections covered by a single instructor, with student support, while preserving the same quality of education received in our traditional, small-classroom method. In our paper, we fully describe our inverted model, share our experiences with it, and provide initial data supporting our claims.

Introduction

The inverted classroom model of teaching has widespread appeal in the educational community. The classroom is inverted or "flipped" because the lecturing occurs at home and activities are done in class. Recent advances in online and educational technologies facilitate off-site lecturing, freeing the course instructor to guide students through challenging activities in class. It seems this model has hit the sweet spot between incorporating online educational technology and providing quality face-to-face time with students. Published benefits of this model include higher student engagement, increased peer learning, lowered student frustration, and the ability of the instructor to provide immediate, direct feedback to students.[1,2,3,4]

Flipped classrooms are gaining respect as a middle ground between traditional instruction and Massive Open Online Courses (MOOCs). While the efficiencies and broad reach of a MOOC are attractive, the MOOC approach suffers very high dropout and failure rates.[5] And MOOCs are not suited to all students, as shown for instance in the difficulties faced by San Jose State University in their experiment with Udacity, offering remedial classes online. For these reasons, we've focused on the inverted model, augmenting it to modestly increase availability and thus throughput for selected classes, while carefully maintaining instructional quality and individual student attention and interaction. Specifically, our augmented version of inverted instruction allows our faculty to roughly double the number of sections they can teach of a particular class in an academic quarter. We hope that augmented inverted instruction might provide a measured and constructive response to the call for greater efficiency and cost reduction in higher education.

Most inverted instruction experiments maintain the same instructor/section ratio as traditional classes. But the model we've spent the last 18 months developing and refining involves one instructor teaching multiple parallel sections with TA support. Our model, which we term high-efficiency inverted instruction, allows us to reap the benefits of inverted instruction for certain courses without reducing our student success rate. Below, we fully describe our inverted model, share our experiences with it, and provide initial data supporting our claims.

High-Efficiency Inverted Instruction

We have made key changes to the classic inverted instruction model in order to scale it up to handling 200+ students. Before describing our model in detail, we first provide guidelines for choosing which courses are appropriate for high-efficiency inverted instruction.

Which Classes Are Suited. Like all things, pedagogical models should be used in moderation and applied only where appropriate. MOOCs, online learning, inverted instruction, classical lecturing and others have potential uses in any curriculum if applied judiciously. In the same way, the model we describe is suited only to certain courses. The necessary conditions a class must meet are:

1. A significant number of sections taught per term, at least enough to occupy two full-time instructors.
2. Subject matter suitable for recorded lecture.
3. Reasonably mature student body able to work with online materials requiring good self-discipline, e.g. not fall term freshmen.
4. Subject matter that does not rapidly evolve, so that investment in recordings and perhaps automated grading is worthwhile.

It is also helpful if most student homework and projects are evaluable by automated systems. Point 2 is of particular interest. Experience with online instruction of remedial students, such as the Udacity experiment at CSU San Jose, suggest that the less structured nature of online teaching may be a poor fit for remedial or less mature students.

Description of the Model. Our high-efficiency model follows the standard inverted instruction practice of recording lectures for viewing outside of class, reserving class time for projects and student assignments, with coaching and assistance from the instructor. The essential elements we add to this are:

1. A rigorous and highly selective process of hiring and training student TAs
2. One instructor running multiple sections of the course in parallel, with TAs supporting the instructor
3. Office hours held both in person and via email and course wiki

Two important additional elements, not strictly essential, are:

1. An automatic grading system that goes beyond the standard online multiple-choice or short-answer tests
2. Full transcripts to accompany the recorded lectures

Highly selective hiring and training. Using TAs to assist instruction is nothing new, of course, and is sometimes controversial. There is evidence, however, that TAs can improve face time for classes having 30-50 students.[6,7,8] What makes our model different in this regard is the selectivity of our hiring process and the very close teamwork between TAs and course instructor during the inverted instruction sessions. The quality of TAs is essential to the model's success. We hire excellent students who are good communicators, often inviting promising students in one term of the course to apply for TA roles in later terms. Our hiring process includes discussion of teaching methods, role-playing walkthroughs of instructional scenarios, and trial sessions in our student tutoring center, under observation of experienced tutors. Less than half of candidates make the bar. We also run a small course specifically devoted to tutoring and teaching methods for our subject area. This year we'll be adjusting the course so that it may be taken every term, for 1 unit of credit, by the inverted-instruction TAs. And importantly, we use TAs only for student coaching, whatever hand-grading may be needed, and fielding routine student Emails, all under instructor supervision. The inverted model obviates the need for TAs to give lectures, or design course content, and any serious student concerns regarding course pressures, academic advising, etc. are referred to the instructor. The instructor's role is a mix of refining and improving recorded course content and automated exercises, direct interaction with students in lab sessions, coaching and management of the TAs, and dealing with non-routine student questions requiring more experienced judgment.

Running multiple parallel sections. We run multiple sections of the course in parallel, in adjacent lab rooms, typically with one TA per room and the instructor rotating between rooms. This time is devoted to helping students do course homework and projects. This allows the instructor and TAs to provide typical flipped classroom activities in the same timeframe of one course. A typical course day starts with the instructor and TAs holding a brief standup conference. TAs share any instructional issues they have observed (e.g. common student difficulties with an assignment, lecture clarifications that might be useful, questions regarding how best to address a point of confusion on an exercise). The instructor offers guidance and makes decisions on issues as needed. As class starts, the instructor rotates through each section to make daily announcements. These are posted online as well, but briefly delivering them in person gives contact time with the instructor at the start of each class. The instructor then observes the TAs working, offers guidance on tutoring methods, and also works directly with students in order to maintain a good understanding of student challenges.

Office hours via email. The instructor holds regular in-person office hours, and there is an in-person evening tutoring center staffed by students. But, most out of class assistance is done via Email, with TAs sharing the load of fielding Email questions, and the instructor overseeing the Email interaction via CCs. Such oversight generally takes little instructor time once TAs have been trained. Questions that are common, and of value to the entire course, are posted onto a course Wiki. This system provides students with assistance at almost any time, generally within a few hours of sending an Email.

Automated grading system. The 357 course uses a mastery model that includes dozens of small programming problems illustrating course concepts, along with larger programming labs, and two major projects. All must be completed perfectly in order to pass the class, and students generally require multiple tries per assignment. While all student work could be hand graded, a good automated grading system saves TA and instructor time. Our system is hand-built by one of the authors, and offers automated grading of programs, style checking, and a metric for code complexity. Mastery learning – requiring perfect completion of all assignments -- is not essential to the model under study, but it does illustrate that an inverted model can still be highly rigorous.

Lecture transcripts. All recorded lectures come with full transcripts. Students consistently indicate in surveys that both lecture recordings (voice and video diagrams) and full transcripts are valuable. The former serves visual learners better and is best for fast review or searching for information, and the latter serves auditory learners better, and helps many students focus when absorbing the material. A less obvious benefit of transcripts is that when errors are found in the lectures it's easy to redmark-edit the transcripts, without needing to redo the recordings, if students understand that they must read the transcript in parallel with listening to the recording. A small number of transcript-only edits are tolerable in this case, with revision of the recording (which is much harder) needed only for major changes.

Assessment

We offer approximate measures of the instructional success of this model in two forms – failure rates and surveys. Because of resource constraints, we could not offer both a traditional section and our high-efficiency inverted model at the same time in order to do a more formal assessment of our inverted model. As mentioned in the future work section below, we plan to do more assessment in the 2014-2015 academic year.

Failure rates. The first is a comparison of failure rates between a traditional pair of sections of 357 taught by Dr. Staley in S '12, vs the high-efficiency sections he taught in F'12-F'13. 357 is a notoriously difficult class, and the mastery model makes it even harder. The failure rate in the traditional sections was 30%, which is not rare for difficult CS courses. Average failure rates for the 4 terms (14 sections) thus far taught under the inverted model were 25%. These data may only be taken as rough indications, as the inverted model used somewhat less challenging projects than the in-person S'12 course, and the mastery model that was introduced in S'12 tended to produce a small but significant body of repeat failing students in the following quarters (a few as many as 4 times). The first factor would skew failure rates for the inverted model downward; the second would skew them upward. In all, though, both the available hard data and instructor and student subjective impressions indicate no significant change in failure rates under the new model.

Surveys. More data may be drawn from student surveys that were conducted after each of the 13 sections, totaling 282 respondents. Several questions relating to the inverted model are relevant. One asked the relative usefulness of various aspects of the course, on a scale from 1 (not useful) to 10 (highly useful). In descending order of usefulness these were:

7.9 Projects

7.8 Recorded lectures and transcripts

7.6 Labs
7.6 Automated homework problems.
6.7 In-class assistance
6.4 Email communication
6.2 Live office hours

Interestingly, live office hours trailed the pack, and the recorded lectures took first place. In general, online and automated aspects of the course scored moderately higher than in-person elements. Student comments indicated that recorded lectures were popular because they could be replayed when a concept was difficult, or when the student's mind wandered. Many comments also noted the clarity of the lectures, which we believe is largely attributable to delivering the lectures from transcript rather than ad hoc or from notes. A follow-up question specifically asked the students to rate the relative value of transcripts vs recordings. Given the investment required to fully transcript the course, we almost wished for an indication that they were not needed, but instead, we found that students valued the transcripts a little more highly than the recordings, with 1-10 ratings thus:

- Transcripts
- Recordings

A second body of survey questions asked for comparisons between the inverted model and a traditional model, again on a 1(strongly disagree) to 10 (strongly agree) scale. The results for the following questions were:

- This course taught me at least as much as a typical in-person course
- I prefer in-person instruction to this online model
- I think teaching 357 this way is a good idea

So, students were nearly evenly divided on whether inverted instruction or traditional instruction was preferred, and overall favored inverted instruction for 357 in particular.

Impacts on Efficiency

Experience in teaching 13 sections under this model indicates that an instructor can teach roughly twice the usual number of sections with no increase in workload. In addition, the marginal cost per section drops as more are added, so varying loads per term are easier to manage. In the current term, Dr. Staley is teaching 7 parallel sections of the course to accommodate an unexpected burst of student enrollment. While this would not be a sustainable load long-term, it is manageable for one quarter. The low marginal cost per section also eliminates the "half section" problem, in which demand exists only for about half of a class, forcing either leaving some students unserved, or filling an (expensive) section only halfway. Indeed, for the past year, no student has been turned away from 357 for lack of room.

Related Work

MOOCs presently represent the most talked about method for providing education to a large number of students. While suitable for certain audiences, such as industry professionals, MOOCs suffer from significant plagiarism and severe dropout rates. As a teaching university, we did not feel MOOCs were a viable option for our curriculum.[5] Lockwood and Esselstein suggest that inverted instruction is a good fit for computer science courses[9] and report positive results. In

addition, Talbert claims that flipped classrooms could possibly scale well with appropriate TA support.[8] Encouraged by this work, we felt we could develop a model that implemented inverted instruction in highly efficient way. Largent reports on his positive experience with using inverted instruction in a large CS0 course. We were encouraged by his initial work and have developed a model that has been tested for scenarios involving many more students.

Conclusion

During the Great Recession, our model allowed us to save enough teaching resources to preserve small class sizes in other courses and was a better alternative, in our minds, than pure online courses. We are pleased with initial results and plan to continue teaching our systems programming course in this way.

Future Work

We plan further assessment on the high-efficiency model. In the next academic year, we plan on doing the following:

1. Conducting a small group instructional diagnosis during the teaching of 357 Fall 2014. This is a service provided by our campus' Center for Teaching and Learning and will help us gauge the student learning environment created by our inverted instruction model.
2. Revising the inverted model to come closer to traditional lecture, by offering one or two of the multiple parallel sections as standard lecture, in exchange for students being graded for lecture attendance, to ensure students select standard lecture only if they mean to attend. While this will self-select students, a comparison of relative performance between students attending standard lecture and those taking the fully inverted option may be of value.

Bibliography

1. DesLauriers L, Schelew E, and Wieman C (2011). Improved learning in a large-enrollment physics class. *Science 332*: 862-864.
2. Pierce, R. (2013). Student Performance in a Flipped Class Module. In R. McBride & M. Searson (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2013* (pp. 942-954). Chesapeake, VA: AACE.
3. Tina Rosenberg (2013). Turning Education Upside Down. *The New York Times*. October 9, 2013. http://opinionator.blogs.nytimes.com/2013/10/09/turning-education-upside-down/
4. Bergmann, J. & Sams, A. (2012). Flip your classroom: Reach every student in every class every day. Washington, DC: International Society for Technology in Education.
5. Mark Guzdial (2014), MOOCs Need More Work; So Do CS Graduates, *Communications of the ACM, vol. 57*, no. 1.
6. David L. Largent (2013). Flipping a Large CS0 Course: An Experience Report about Exploring the use of Video, Clickers, and Active Learning. *Journal of Computing Sciences in Colleges 29(1)*, 84-91
7. Gannod, G.C, Burge, J.E. and Helmick, M.T. Using the Inverted Classroom to Teach Software Engineering. In *ICSE 2008*, Lepzig, Germany.
8. Talbert, R. Using MATLAB to Teach Problem-Solving Techniques to First-Year Liberal Arts Students. MathWorks, Inc., 2011
9. Lockwood, Kate and Esselstein, Rachel (2013). The Inverted Classroom and the CS Curriculum. *SIGCSE 2013 Proceeding of the 44th ACM technical symposium on Computer science education, ACM*, 113-118.