TRANSFORMING AN UNDERGRADUATE INTRODUCTORY BIOLOGY COURSE THROUGH CINEMATIC LECTURES AND INVERTED CLASSES: A PRELIMINARY ASSESSMENT OF THE CLIC MODEL OF THE FLIPPED CLASSROOM

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ABSTRACT

Two sections of an undergraduate introductory Biology lecture course were run in parallel as a pilot pedagogical experiment. One section (N = 32) was taught in a long-established, traditional manner, with lectures delivered during class, readings assigned in a textbook, and access to lecture graphics/slides provided via the online syllabus. The other, "flipped" section (N = 16) lacked both required reading assignments and in-class lectures. Instead, students were assigned online cinematic lectures (*cinelectures*) for viewing outside of class. In class, students were broken into small groups and engaged in active learning assignments. This model of flipping is termed CLIC (Cinematic Lectures and Inverted Classes). Accounting for all sources of content, the subject material covered was the same for both sections and assessments of learning were identical quizzes and examinations. Statistically significant differences in learning were observed during the first half of the semester, with the flipped-class students performing better on all tests and quizzes. These differences disappeared in the second half of the semester, coincident with a large increase in the number of views of cinelectures recorded on the course YouTube channel. Survey of the traditional class revealed that approximately 3/4 of the students had learned of the cinelectures at this time and had added viewing of these to their study, providing an internal, if initially unintended, control sample to the experiment. These results, along with other analyses, provide preliminary but strong evidence that supports the conversion of traditional Biology lecture classes to a CLICed model.

INTRODUCTION

This report describes an experiment in the implementation of a particular model of classroom flipping of an introductory Biology lecture course at a small, comprehensive university. Because flipping is becoming increasingly popular, especially in K-12 education, and because assessment of the effects of this type of reform at the post-secondary level are sorely needed, our study bears import for a wide range of Biology educators.

The Need for Active Learning in Undergraduate STEM Education

> *"A lecture is a process by which the notes of the professor become the notes of the student without passing through the minds of either."* – R.K. Rathbun (cited in Alberts, et al., 2007)

Limitations of traditional lectures as a primary pedagogical tool in teaching science have been widely recognized over the years, satirically in some cases. Unfortunately, this class format prevails as the most common approach to Science, Technology, Engineering, and Mathematics (STEM) education at the post secondary level. STEM courses should help students integrate basic concepts into conceptual frameworks, link prior learning to new knowledge, and develop reasoning and problem solving skills that allow the application of concepts to situations that are not explicitly memorized. However, these goals are rarely realized for the majority of students in the traditional lecture model (e.g., National Research Council (NRC), 2000; McCray, et al., 2003; Honan, 2002; Knight, 2004; Freeman, et al., 2011). For most students, lecturing promotes memorization of facts rather than fostering deep understanding (e.g., Wright, et al., 1998; Loverude, et al., 2002), and even high academic achievers sometimes gain little understanding of basic science concepts through traditional didactic lectures (Sundberg, 2002).

To remedy this situation, numerous clarion calls for reform of standard lecture delivery by incorporating *active learning*[1] (AL) in the classroom have been forwarded by august science education advisory bodies (e.g., Froyd, 2007 (Project Kaleidoscope); Davis, 1997 (National Research Council - NRC); Nielsen, 2011 (NRC); NRC, 2000, 2003, 2004; National Science Foundation, 1996; The Boyer Commission, 1998; Bonwell and Eisen, 1991 (The Educational Resources Information Center); Cerbin, 2012 (The Carnegie Foundation for the Advancement of Teaching). In terms specific for undergraduate Biology education, a call to action has been published by AAAS (2009).

Indeed, there is a broad empirical fundament that supports the use of AL in science classrooms [e.g., reviewed by Handelsman, et al. (2004); Prince (2004); Knight (2004); Allen and Tanner (2005)]. Specific examples of the benefits of AL in undergraduate Biology education include: 1) Haak, et al.'s (2011) observation that substituting daily and weekly practice in problem-solving, data analysis, and other higher-order cognitive skills for lecture-intensive course design improved the performance of all students and reduced the achievement gap between disadvantaged and nondisadvantaged students; 2) Derting and Ebert-May's (2010) finding that an intense, inquiry-based, learner-centered experience was associated with long-term improvements in academic performance; 3) Knight and Wood's (2005) measurement of significantly higher learning gains and better conceptual understanding when student participation and cooperative problem solving during class time was substituted for traditional lecturing; 4) Burrowes'(2003) evidence that teaching Biology in an AL environment is more effective than traditional instruction in promoting academic achievement, increasing conceptual understanding, developing higher level thinking skills, and

1. The term ***active learning*** **(AL)** may acquire different, contextual meanings, but it is generally understood as pedagogy in which students are encouraged to develop their learning autonomously. AL requires students to ask questions of themselves and their peers in solving problems, in contrast to passively receiving information. Process-oriented, guided inquiry learning (POGIL), peer-led team learning (PLTL), problem-based learning (PBL), and Investigative Case Based Learning (ICBL) are often components of an AL environment (e.g., Eberlein, et al., 2008).

enhancing students' interest in Biology; 5) Udovic, et al.'s (2000) observation of pronounced differences between students taught biology traditionally and those taught with a series of active, inquiry-based learning modules, termed "Workshop Biology."

Despite its documented value, there remain formidable barriers to incorporation of AL in the classroom, and traditional lectures remain the norm for most introductory science classes (e.g., Stokstad, 2001; Wood and Gentile, 2003; Allen and Tanner, 2005). These barriers include academic cultures that sometimes undervalue teaching innovations, professorial habits revolving around lecturer-centered education, the necessity of delivering copious amounts of content in a single quarter or semester, the perceived efficiency of lecturing to students in notoriously large introductory classes, and student skepticism regarding the value of and participation in active learning (e.g., Hanford, 2012).

The Flipped (CLICed) Class as "Disruptive Innovation"

> *"I think [the traditional lecture] is going to be kind of blown away in favor of a model where every student is working at their own pace and the teacher now has a much higher-value role…"* - Salman Khan (2012)

> *"The key to the flipped class is actually not the videos, it is the freedom those videos give the teacher to have engaging class activities and interaction with their students."* - Jon Bergmann (2011)

A method of introducing AL pedagogy in the undergraduate lecture hall that overcomes some of the previously mentioned barriers to its implementation is the approach known as class inversion or "flipping," i.e. assigning material as homework that is usually covered in lecture and engaging students in AL during class. This approach to classroom inversion is not new and there are many different models of class flipping (e.g., Baker, 2000; Lage and Platt, 2000; Sams, 2010), but one model that has recently gained momentum has been popularized by Salman Khan (www.khanacademy.org). This approach, which we term **CLIC** (**C**inematic **L**ectures and **I**nverted **C**lasses) in order to distinguish it from other flipping formats, relies on the delivery of course content through engaging, cinematic lectures outside of class, which enables the transformation of classrooms into arenas of inquiry and active learning (Figure 1). This idea has captured the attention of the educational and popular press (e.g., Berrett, 2012; Ojalvo and Doyne, 2011) and has been sweeping K-12 educational communities.

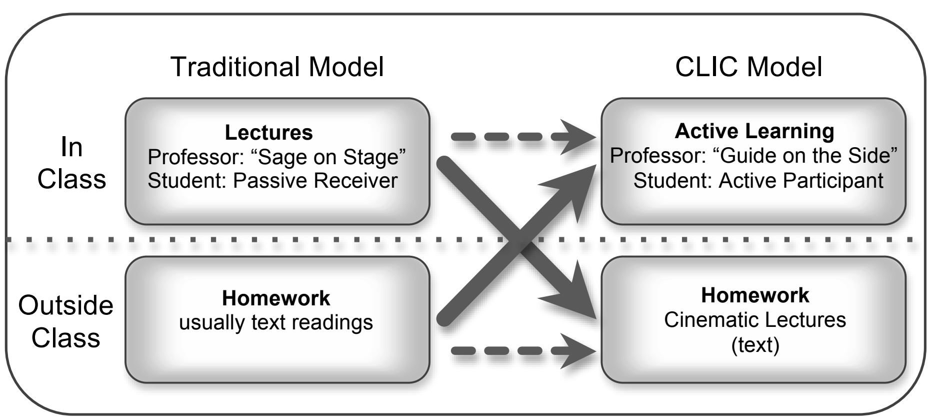

Figure 1. Inversion of Biology and Physics lecture courses from a traditional to an inverted format. In the CLIC model (CLIC = Cinematic Lectures & Inverted Classes), students view online, engaging, cinematic lectures outside class (with optional text consultation) and participate in collaborative, inquiry- and problem-based activities in class. This transforms the standard roles of both student and professor, the latter of which is a long-advocated switch from "Sage on Stage" to "Guide on the Side" (King, 1993).

In terms of online learning, CLIC can be viewed as a subset of those formats termed blended or hybrid, involving both online and face-to-face learning (e.g., Garrison and Kanuka, 2004; Reasons, et al., 2005; Alberts, et al., 2007). There is substantial research in cognitive information processing (e.g., reviewed in Walker, et al., 2011) and in evaluation of blended learning that supports the use of online multimedia in learning activities (e.g., McFarlin, 2008; Lentz and Cifuentes, 2009; Kay and Kletskin, 2012). Walker, et al. (2011) report a significant gain in learning outcomes for introductory Biology students using multimedia vodcasts compared to those viewing class lecture-capture videos, and Sadaghiani (2012) found that online prelectures followed by analytical problem solving in the classroom increased student understanding in introductory Physics classes.

The theoretical advantages of CLIC for post-secondary education are pronounced. CLIC enables professors to deliver course content asynchronously to students who can engage the online cinematic lectures (*cinelectures*) on their own terms, viewing them on computers or mobile devices at their own convenience and pace and, importantly, reviewing portions that they wish to understand more thoroughly at will. This, in turn, makes possible the transformation of lecture classes into venues where AL can be implemented. These two critical elements together can provide a more effective learning environment than the traditional lecture model. This game changing approach is a canonical example of "disruptive innovation" (e.g., Christensen, et al., 2010) that is being actively promoted by online teaching networks (e.g., www.flippedlearning.com; www.vodcasting.ning.com; www.flipteaching.com). CLIC has garnered some criticism. Most objections, however, concentrate on the inability of online video to engage students in inquiry-based activities (e.g., Noschese, 2012), thereby ignoring the *raison d'être* of the CLIC.

CLIC is still in very early phases of adoption at the university level, and other than the study of the effects of this model that we report below, we are not aware of an assessment of this precise form of class flipping in undergraduate Biology classes.

A PEDAGOGICAL EXPERIMENT IN IMPLEMENTATION OF CLIC

Research Design

Recognizing both the potential value of CLIC and the need for assessment of this type of reform at the undergraduate level, we ran a pilot experiment in CLICing in Fall semester, 2011. Two sections of a one-semester, introductory Biology lecture course (Introduction to Metabolism, Genes and Development[2]), taught by the same professor, were run in parallel. One section (32 students) was taught in a long-established, traditional manner, with lectures delivered during class, readings assigned in a textbook, and access to lecture graphics/slides provided via the online syllabus. The other, CLIC section (16 students) lacked both required reading assignments and in-class lectures. Instead, students were assigned online cinelectures for viewing outside of class. These cinelectures, delivered via links to YouTube from the course online syllabus, incorporate multiple presentation media. In class, students were broken into small groups and conducted AL activities that varied from building physical molecular models to constructing concept maps of key topics. Often, these groups were responsible for presenting material to the class as a whole.

There was no significant difference between the sections in either overall or science GPAs at the beginning of the course. Accounting for all sources of content, the subject material covered was the same for both sections and assessments of learning were identical quizzes and examinations. We hypothesized that significant differences in learning outcomes and in student perceptions of the course would be observed, demonstrating positive contributions of CLIC reform.

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2. *Introduction to Metabolism, Genes and Development*. This course introduces energy flow within cells, mechanisms of heredity, the expression of genetic information, and the means by which genes encode developmental programs. Emphasis is placed on the concept that genetic mechanisms and developmental controls reveal a fundamental kinship of all life. The tools of genetics, including mutational analysis of model organisms, recombinant DNA, and biotechnology are introduced.

Results

As shown in Figure 1, pronounced differences in learning (quiz and test scores) were observed during the first part of the semester (q1-e1), with the CLICed class students performing

significantly better on all tests and quizzes in this time period (unpaired student t tests, t=2.64, df=46, p<0.01).

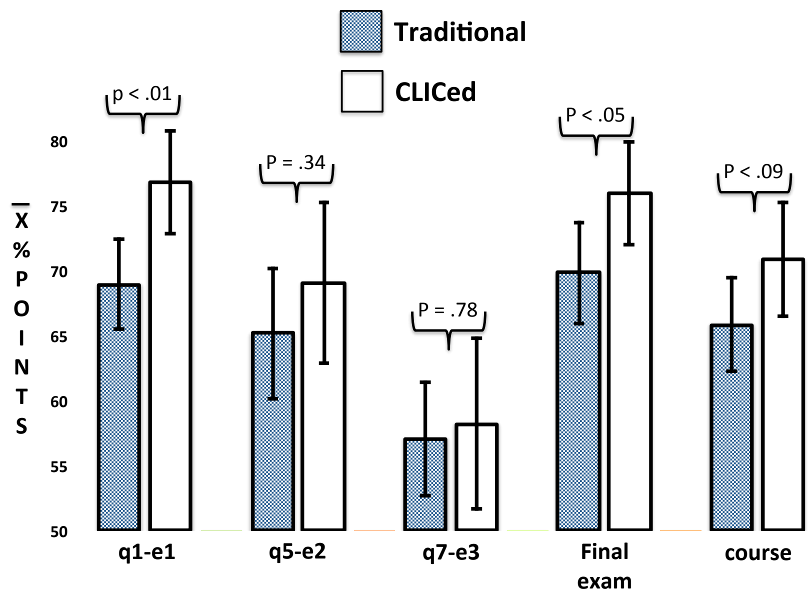

Figure 1. Mean number of percentage of points available on quizzes and examinations for the traditional and CLICed sections, plotted as a function of semester timepoints. Timepoints are defined by quiz 1 – exam 1 (q1-e1), quiz 5 – exam 2 (q5-e2), quiz 7 – exam 3 (q7-e3), final exam, and course total. P values are unpaired student t tests probabilities, df=46. Shaded bars = traditional section, unshaded bars = CLICed section. Error bars are 95% confidence intervals.

As observed in Figure 1, the significant differences in scores observed in the q1-e1 timepoint disappeared in later parts of the semester (q5-e2, q7-e3), but reappeared on the final exam.

Figure 2 displays the number of course website-originated views of cinelectures. Comparing Figures 1 and 2, the disappearance of score differentials in course timepoints q5-e2 and q7-e3 are observed to be coincident with a large increase in the number of course website-originated views of cinelectures. An anonymous, late mid-semester survey revealed that approximately 3/4 of the students in the traditional class had learned of the cinelectures at this time and had added viewing of these to their study, providing an internal, if initially unintended, control to the experiment (i.e., there was no apparent difference in comprehension ability between the sections – see discussion).

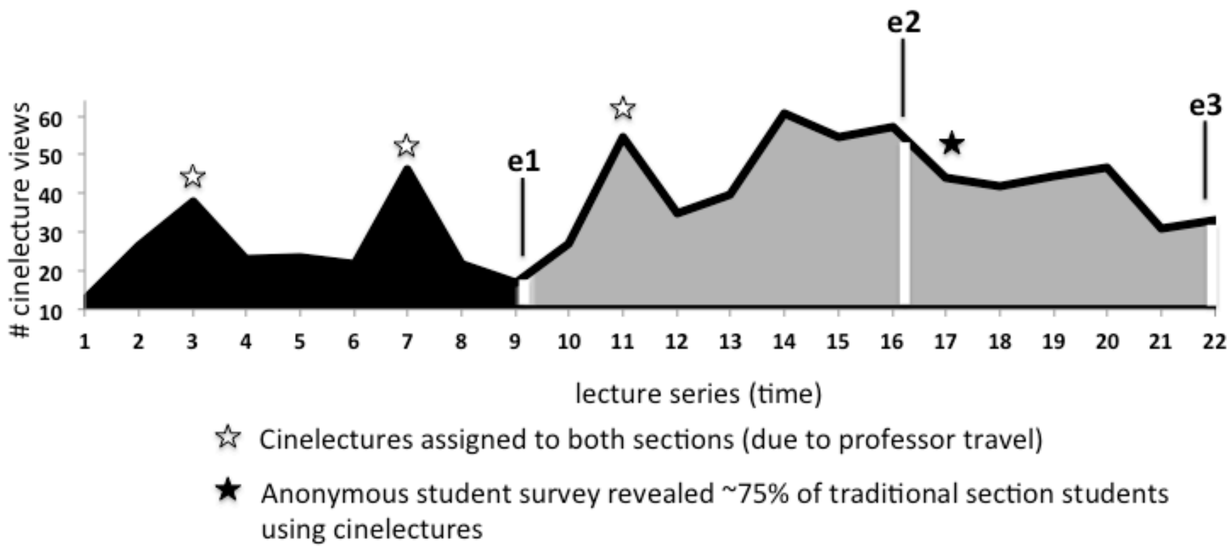

Figure 2. The numbers of course website-originated views of cinelectures plotted over the time course of the semester with examination 1 (e1), examination 2 (e2) and examination 3 (e3) indicated. Unshaded stars mark cinelecture series assigned to both traditional and CLICed sections due to professorial absence. Shaded star indicates the date of an anonymous survey administered to the traditional section (see text).

Table 1 displays Pearson R correlation values between overall science GPAs and scores in the class under study for each timepoint of the semester. This regression analysis indicates that overall student science GPAs were more highly correlated with learning outcomes in the CLICed class for the q1-e1 and overall course timepoints (see discussion).

Table 1. Pearson R correlation coefficients between overall science GPAs and scores in both the traditional and CLICed sections of Biology 122.

Timepoint	R (traditional)	R (CLICed)
q1-e1	0.57	0.90
q5-e2	0.60	0.63
q7-e3	0.42	0.75
Final Exam	0.61	0.54
Course	0.62	0.88

In order to assess student responses to the pedagogy in both sections under study, anonymous, standard, end-of-semester course evaluations were administered through the CLU website. Figure 3 displays results of these surveys for 5 key indicators of student satisfaction.

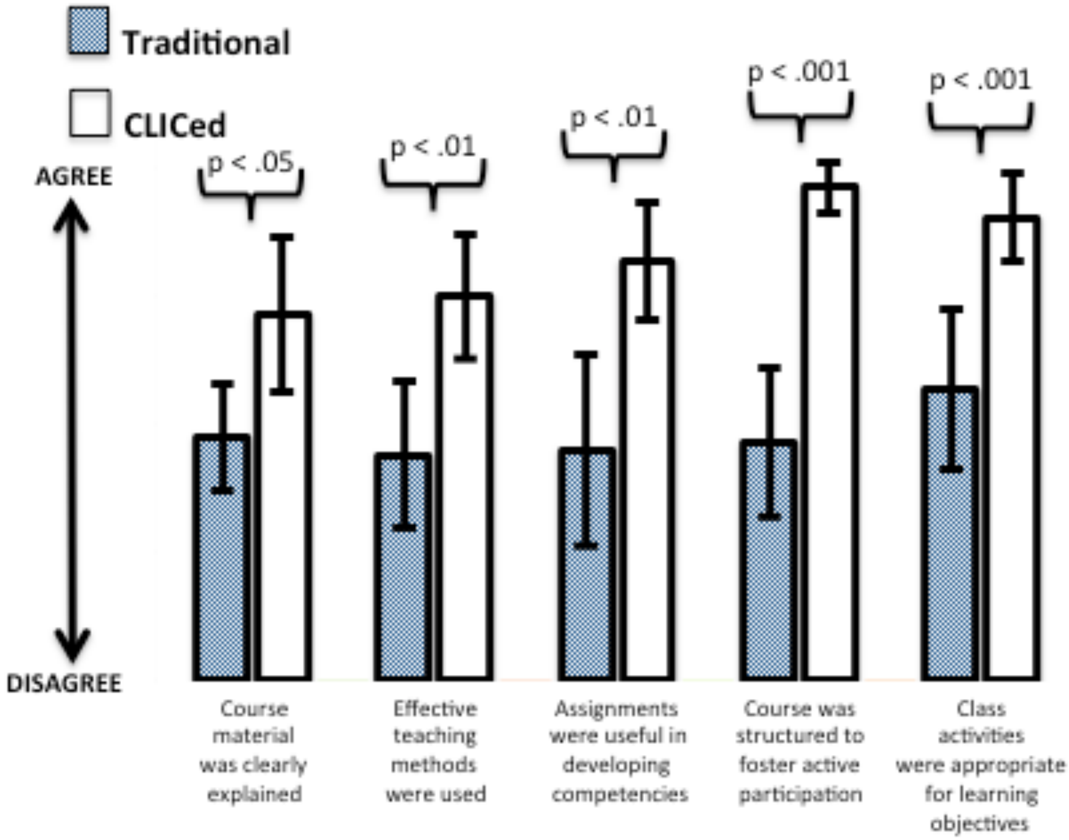

Figure 3. Student responses to the traditional and CLICed sections rated by the degree to which they agree or disagree with five statements regarding course pedagogy. P values are unpaired student t tests probabilities, df=32. Shaded bars = traditional section, unshaded bars = CLICed section. Error bars are 95% confidence intervals.

The results of Figure 3 show highly significant differences (unpaired student t tests) in student perceptions of the two courses. Students in the CLICed course rated their course higher in the following categories: explanation of course material by the professor ($t=2.10$, $df=32$, $p< 0.05$), use of effective teaching methods ($t=2.76$, $df = 32$, $p<0.01$), usefulness of homework assignments ($t=3.01$, $df=24$, $p<0.01$), course fostering of active participation ($t=5.15$, $df=32$, $p <0.001$), and appropriateness of in-class activities for achieving learning objectives ($t=3.27$, $df=29$, $p <0.001$).

Discussion

The learning outcomes and student responses observed in the first part of this pilot experiment provide compelling evidence that supports the conversion of traditional Biology lecture classes to a CLIC model. We observed a noteworthy disappearance of the differences in learning outcomes between the students in the traditional and CLICed classes when the traditional-class students began to view online cinelectures. This result suggests that the cinelectures and not the in-class, active learning exercises were primarily responsible for the discrepancy in test performance observed in the first part of the course. This result is surprising, given the large body of literature that reports significant gains in student learning outcomes as a result of active learning participation in the classroom, e.g. Handelsman, et al. (2004); Prince (2004); Knight (2004); Allen and Tanner (2005); Haak, et al. (2011); Derting and Ebert-May (2010); Knight and Wood (2005); Burrowes (2003); Udovic, et al. (2000). Since this was a pilot experiment in which the active learning modules were being newly developed, we opine that more detailed and engaging active learning pedagogy in the future will result in even greater improvements in learning outcomes, as the literature on active learning suggests (see INTRODUCTION). Future work will examine the effects of refined CLICing on both student learning and on retention of declared Biology majors during their college careers.

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