Improving Student Engagement in Organic Chemistry using the Inverted Classroom Model

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Improving student engagement in STEM (Science, Technology, Engineering, and Mathematics) courses generally, and organic chemistry specifically, has long been a challenging goal for educators. In fact the academically demanding nature of organic chemistry has, many times, the unintended consequence of disengaging students, particularly those that don't immediately see the relevance of the subject matter to their field of study.

Recently educator's at all academic levels are exploring the "inverted classroom" or "flipped classroom" pedagogical model for improving student engagement in subjects spanning the fields from liberal arts to business studies to science and technology. This learner-centered pedagogy, where students are responsible for understanding fundamental course concepts outside the classroom, allows class time to be more productively used for higher level engaging activities such as collaborative and problem-based learning through the instructor led application of the material delivered outside of class.

This paper describes the techniques used to accomplish and the technology employed to deliver an inverted two semester organic chemistry classroom at Gloucester County College. It will also explain and show how each semester topics were divided and presented to the students, and discuss the use of classroom face-to-face time during the semester. Preliminary student performance data vs. the traditional lecture classroom format along with student comments about the inverted classroom approach are also presented.

Introduction

Gloucester County College (GCC) is an open access two-year college located approximately twenty miles south of Philadelphia in Sewell Township New Jersey. Student enrollment is approximately 6700 of which 60% are full-time and 40% part-time. The student body is composed of approximately 57% female and 43% male. The college offers a broad range of two-year Associates in Arts (A.A.), Associates in Science (A.S.) and Associates in Applied Science (A.A.S.) degrees covering a range of courses in the liberal arts, humanities, business, STEM, and nursing and allied health related curricula.

In the area of STEM the college offers a number of course delivery options, see table 1.

Table 1 – STEM Course Delivery Options at Gloucester County College.

Course Delivery Option	Definition	Percentage of STEM Courses Delivered by that Option
Traditional	All classes meet on campus with no online component.	37%
Web-Enhanced	Majority of all class meeting take place on campus, with less than 25% of course conducted online.	45%
Hybrid	50 to 75% of all class meetings are on campus, with the remaining class sessions conducted online.	15%
Online	All course requirements completed online.	3%

Instructors at all levels of education in many different courses have struggled with the issue of developing and retaining active student engagement in their course work (1,2). This problem is particularly prevalent in the sciences (3-5). Many articles have appeared describing methods to address this issue specifically in the chemical sciences (6-15). Organic chemistry is particularly challenging because of the complex nature of the subject and the apparent disconnect that many students feel since applicability of the topics learned may not be immediately obvious. Also, more active engagement in the first semester of organic chemistry is critically important for student retention and success in the second semester of the course.

At GCC a two semester sequence of organic chemistry from its inception in the late 1960's had been taught using the traditional lecture format. In the late 1990's the course was transposed to a web-enhanced format where supporting course information was placed online for students to access, but all classes still met on-campus for a traditional lecture. Students that take organic chemistry typically major mainly in science with chemistry or biology (~66%) making up the vast majority (figure 1).

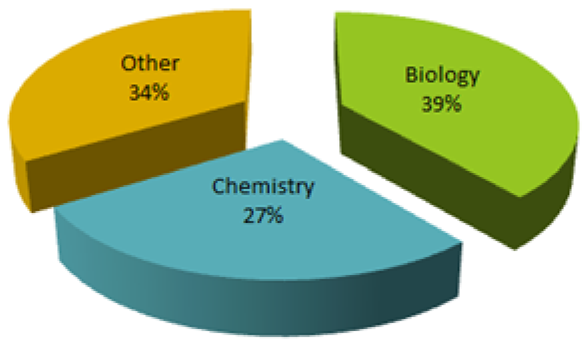


Figure 1 – Typical student composition by major taking organic chemistry at GCC.

In recent years seven sections of organic chemistry, each containing between 20 and 24 students, have run at GCC. Typically four sections are run in the fall semester (three of organic I and one of organic II), and three in the spring (one of organic I and two of organic II). Although the traditional pedagogical style worked for some students, the majority of the population was not fully engaged, as evidenced by a steady decline in first semester examination score averages. Figure 2 illustrates this declining exam average trend for the four exams given in the semesters shown.

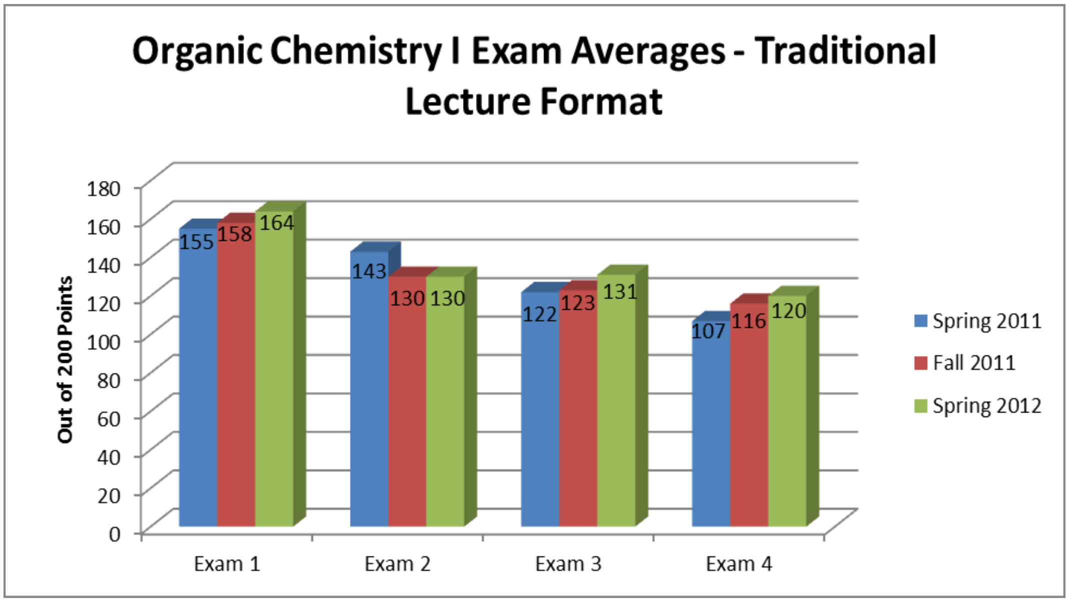


Figure 2 – Student examination averages out of 200 points for three semesters of traditionally taught organic chemistry I classes.

In recent years there has been an explosion in the number of published articles describing a new pedagogical approach to learning referred to as the "inverted" or "flipped" classroom (figure 3).

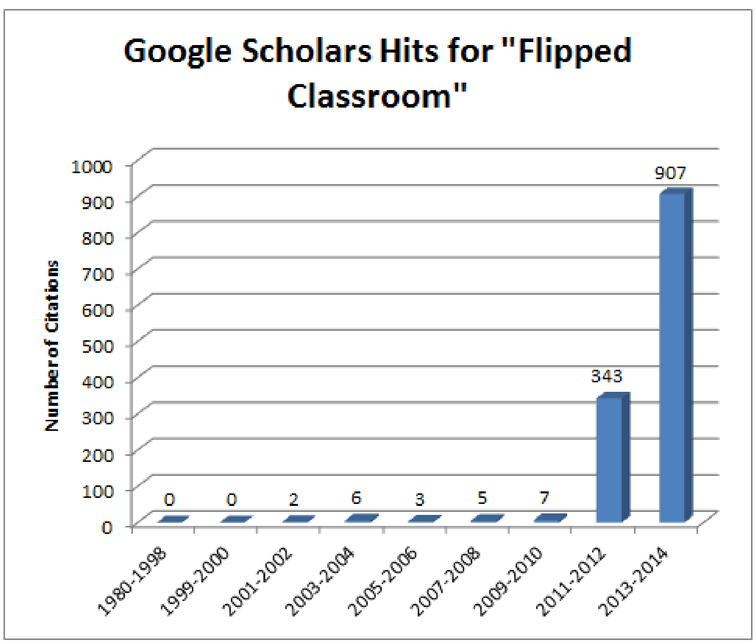


Figure 3 – Google Scholar citation hits for the term "Flipped Classroom".

Characteristic of this approach is to have course content delivered to students outside the classroom, as assigned homework, and classroom face-to-face time spent doing instructor led higher order learning activities (16a,b). Although the most recent upsurge in interest for this teaching style is taking place at grade levels K-12 (17,18), its origins can arguably be traced back to the U.S. Military Academy at West Point in the 1820's where superintendent Sylvanus Thayer, an engineer, implemented what is now known as the Thayer tenets of education (19,20), and the Harvard Law School in the 1890's where Dean Christopher Columbus Langdell introduced the concept of the case study method (21). Both educators' methods favored a student-centered approach, where the student takes more responsibility for his or her learning.

This approach has gained popularity recently as a result of advancements in the cost, ease of use, and availability of technology to deliver online course content (22). A more up-to-date characterization of the inverted classroom typically incorporates the use of lecture video capture and the ability to stream those videos to the student via the internet (23). This method gained immediate favor in K-12 education undoubtable due to the popularity of video lessons already available on such sources as YouTube and more notably the Khan Academy (24). Now, not only has higher education adopted this approach (25) but even medical schools have begun to embrace this pedagogical style (26a,b). Some of the reported advantages include:

1. Students are able to cover material at their own pace,
2. Problem solving in-class gives instructors insight into concepts students find most challenging,
3. Classroom time can be used more creatively, for higher order learning activities,
4. Increased student engagement,
5. More time can be spent with students that need it the most,
6. Students never miss lecture.

Although there are many methods that can be used to invert the classroom, the method chosen and reported here involves the use of lecture video capture and delivery of the video content to the students through the internet. This paper describes the techniques used and the technology employed to deliver an inverted two semester organic chemistry classroom at Gloucester County College. It will present how each semester topics were divided, and discuss the use of classroom face-to-face time during the semester. Engagement, as measured primarily by student performance data on exams and total points earned during the semester vs. the traditional lecture classroom format and more anecdotally by observing class participation, along with student comments about the inverted classroom approach is also presented.

Video Lecture Production: Technology and Format

There are a number of ways in which video lectures can be produced. Some instructors prefer to have their lectures recorded in real time while others favor a time separate from their normal lecture in a studio setting, using the same lecture material (e.g., PowerPoint slides) employed in the traditional lecture, only with a voice-over recording (23). The first approach typically requires more elaborate video recording capabilities and in the latter case a special studio may even be needed. The development of websites such as “Educreations” (27) and “ExplainEverything” (28), which allow recorded video via apps on your computer or mobile device, have made self-recorded lectures more viable. Yet still another approach utilizes a “LiveScribe” (29) pen to capture video of hand-written topics when used with special paper.

The method chosen for organic chemistry at GCC follows in the style developed by the Khan Academy, where the viewer sees a blackboard background upon which colored writing appears, and hears only the voice of the instructor (24). It turns out that production of these types of videos is rather simple to do at minimal cost.

Hardware

These Khan Academy style videos can easily be produced using any type of personal computer. If the computer does not have a touch screen, then a USB tablet with stylus will also be required in order to be able to write the information on a defined portion of the computer screen (30).

Software

There are a number of screen-capture software programs on the market that can be used to capture lectures on the screen of your computer with audio. For this work Snaget, a relatively inexpensive no thrills version of Camtasia, produced by the same manufacturer, was used (31). All screen-capture software allows the capture of video for a user defined specific region of the computer screen. Because an older version of Snaget (Snaget 9) was used to create the videos for this paper, video was produced in the very large avi (Audio Video Interleave) format. Therefore video file conversion software was also employed once the videos were produced in order to save them as compressed mp4 or wmv (Windows Media Video) files (32).

In order to write and have that writing appear on the computer screen digital free-hand drawing software, commonly used by digital artists, was needed. For this paper the freeware SmoothDraw, downloadable from the suppliers’ website, was employed (33). The software produces a “canvas” screen which allows the user to change the background/writing surface color, style of pen, and produce writing layers on the background surface, which can also be of different colors. This gives the appearance of a “blackboard” background with writing layers that simulate “colored chalk” to the viewer. The software also recognizes PowerPoint figures which can be cut and pasted onto the canvas, allowing direct writing on those figures.

Once the videos are produced they need to be housed on a site accessible to the students via the web. Some faculty use YouTube, while others post their videos directly to their colleges web based learning system like Blackboard. Because of the large video file size, even in reduced mp4 and wmv file formats, coupled with the large number of videos produced and the potential large number of students trying to access the videos simultaneously, housing and streaming the videos became more practical using the services of the remotely located host server service CollegeAnywhere (34). CollegeAnywhere is capable of streaming the videos back to the student on any PC either through the web based learning system (e-Learning or Blackboard) or the students can be supplied the URL for each video lecture in a MSWord document which would then allow the student to access the video directly. In order to accommodate Apple based mobile devices however, i.e., i-Pads and i-Phones, it was necessary to save the Word document containing the video URL's as a Google Doc published to the web. Students wishing to use their Apple mobile device would then simply access the Google Doc through a supplied URL.

Video Lecture Topics and Assignment

For the two semester course in organic chemistry at GCC more than 340 video lectures were produced totaling approximately 43 hours of video viewing time for semester one and 45 hours for semester two. This represents slightly more time than the actual lecture time typically allocated for an integrated lecture/laboratory fifteen week course that meets for five hours per week where slightly less than half that time is spent in the laboratory with the remainder spent in a traditional lecture. Video lecture topics were prepared in mostly 10 to 20 minute segments, with the number of topics exceeding twenty minutes kept to a minimum (35). Some topics required three or four videos to cover concepts completely. Table 2 illustrates a sampling of the typical video lecture topics and the video length for both Organic Chemistry I and II.

Table 2 – Sampling of Typical Video Lecture Topics Produced for Organic Chemistry I and II.

Organic Chemistry I	
Video Lecture Topic	**Video Length (minutes:seconds)**
Representing Organic Structures	7:28
Counting Hydrogens on Carbon in a Skeletal Structure	5:16
Introduction to the Rules of Resonance	12:32
Summary of Allowed Electron Movements in Resonance	13:12
Introduction of Organic Reactions	16:20
Introduction to Ionic Nucleophilic Substitution	23:58
Organic Chemistry II	
Introduction to Conjugated Systems	15:49
UV Spectroscopy – The Basics	27:06
Electrophilic Aromatic Substitution	11:16
Friedel – Crafts Acylation	11:17
The Nature of the Carbonyl Group	5:49

It is important to note that the lecture videos produced were intentionally made mainly unrehearsed and unscripted keeping the same type of natural conversational flow that the student would normally experience in the face-to-face traditional lecture. Also, when undetected errors were made during the production of the video, rather than going through the arduous process of editing the video and splicing in a corrected segment, a separate, short "addendum" video was instead produced and listed right after the effected video for students to watch. Although the unrehearsed nature of the videos and the need to occasionally make correction addendum videos had a negative impact on video time length, they both served to impart more human characteristics to the video lectures which can better relate to the students (36).

Video lectures were typically assigned to the class in approximately 2.5 to 3 hour segments per week, depending on the topics covered and what would make a good cut-off point.

Classroom Face-to-Face Time

Now that the students were reviewing and studying the lectures out of class it was important to optimize classroom face-to-face time with deeper learning, problem solving activities. The challenge, however, would be to utilize this time in such a way that would engage the student, or risk it becoming an unengaging conventional "recitation period".

Class would typically start with the instructor asking questions about some of the key concepts presented in the videos, keeping an eye out for some of the tell-tale signs that the assigned videos were not being studied e.g., lack of student participation and students not referring back to their notes taken on the videos. At this point, it was not unusual for the instructor to proceed to give a "mini-lecture" reviewing those concepts that were obviously giving the students the most trouble.

Upon first introduction of the inverted classroom, the remaining face-to-face time was spent with the instructor doing most, if not all, of the assigned text problems at the board, while asking students for assistance. This method was employed for the first two semesters, but it quickly became apparent that during this part of the class students became disengaged and fell back into a note taking mode as if attending a traditional lecture, rather than attempting to solve the problems along with the instructor. How were they going to learn if they were not attempting the problems on their own first?

In subsequent semesters the problem solving portion of the class time evolved into a collaborative/peer learning format by breaking the class into teams of students and either assigning the same problem to each team or using different problems that illustrated the same concept (37). Team sizes typically varied from two to as many as six, depending on class size and the individual student comfort level. This format afforded the student the opportunity to engage in the problems on their own and at the same time working in a team for support and peer guidance. The instructor now became a "coach" that roamed from team to team willing to answer questions, lend support and further direction as needed and, at times, engaged in deeper concept discussions, far beyond what could ever occur in the traditional class style. Once most of the teams appeared to have solved their assigned problem, a volunteer from each team proceeded to place their agreed answer on the board. At that point more discussion takes place as needed.

This format was found to be by-far the most engaging and typically leads to a class period that looks nothing like the traditional, with learning occurring at various levels within the teams and organic chemistry conversations carried on by the students. There was truly chemistry being spoken here!

In an effort to assure that the majority of students indeed understood the material a set of clicker response system questions were implemented (38). Multiple choice clicker questions were randomly placed throughout the PowerPoint slides containing the in-class questions, for students to answer either individually or after team discussion. These questions would specifically challenge the students on the very concepts that they just worked on as a team. Occasionally the clicker questions were even offered as an opportunity to earn bonus points toward their grade, acting as further incentive to participate and learn the material during these sessions.

Student Outcomes (39a,b)

<u>Organic Chemistry I</u>

Figure 4 shows the results of the averages of the four exams taken in organic chemistry I for the three semesters in which the inverted classroom pedagogy was utilized. Notable is the improvement in exams 2, 3 and 4 score averages relative to the three previous semesters taught using the traditional lecture format (figure 2).

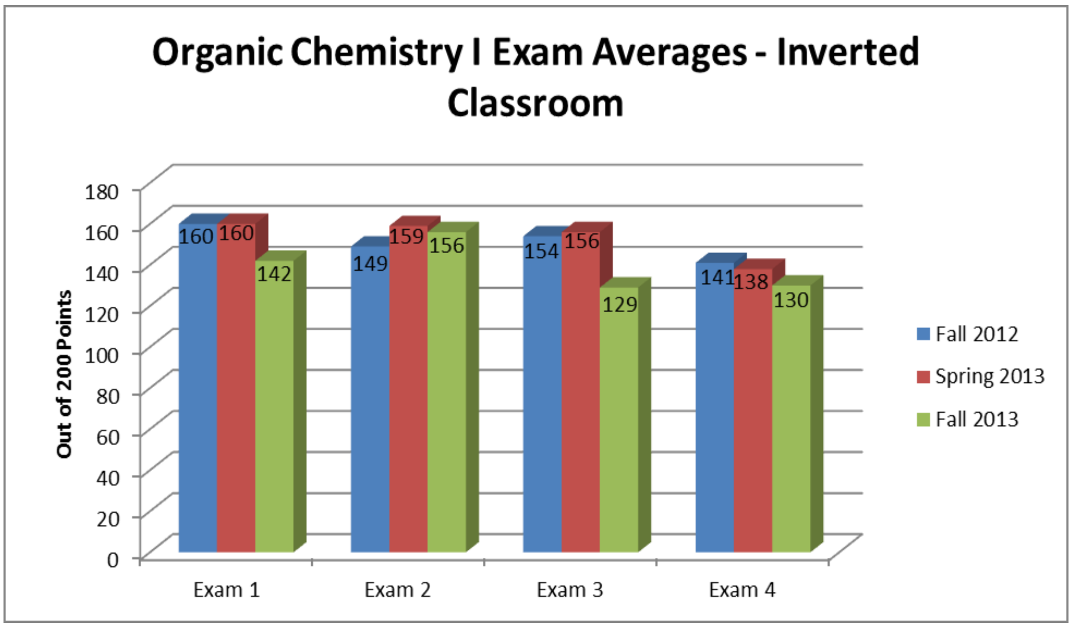


Figure 4 - Student examination averages out of 200 points for three semesters of inverted classroom organic chemistry I classes.

Also notable was the marked improvement in student averages of the total semester points scored by the classes that were inverted (figure 5, Fall 2012, Spring 2013, and Fall 2013) relative to the three previous semesters traditionally taught (figure 5, Spring 2011, Fall 2011, and Spring 2012).

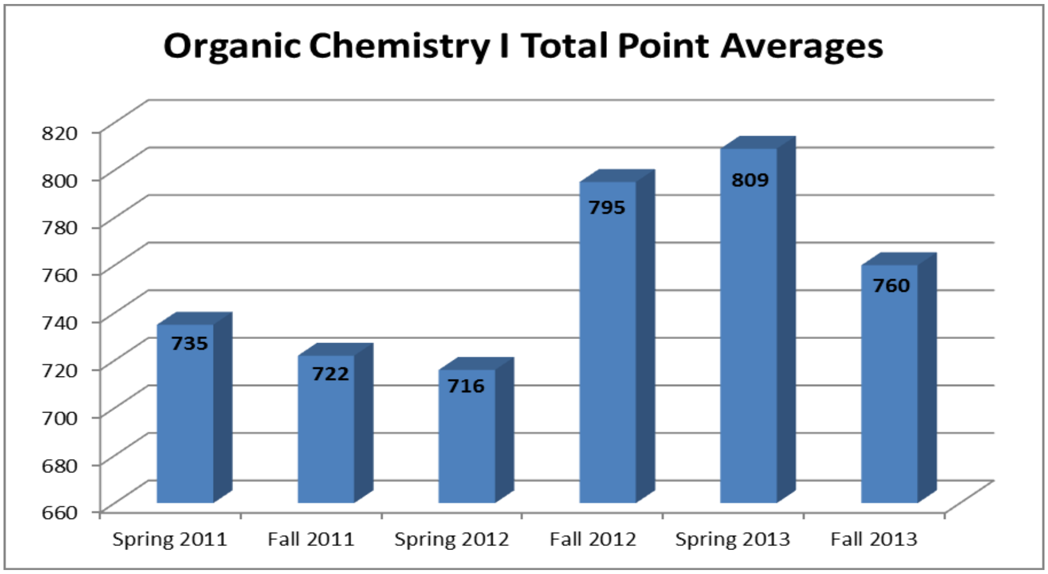


Figure 5 - Student total semester point averages out of 1000 points for three semesters of traditional classes (Spring 2011, Fall 2011, and Spring 2012) vs. inverted classroom (Fall 2012, Spring 2013, and Fall 2013) organic chemistry I classes.

Organic Chemistry II

Although having less semester experience with organic chemistry II in the inverted format than organic chemistry I, this same basic trend in both exam averages and total student semester points can be seen. Figure 6 compares student exam averages for the two previous semesters of traditional lecure format (Spring 2011 and Spring 2012) with two semesters of the invered classroom (Spring and Fall 2013). In organic chemistry II, unlike organic chemistry I, only 3 exams, each out of 200 points, are given for the entire semester. Again some improvement is witnessed, particularly for exams 1and 3.

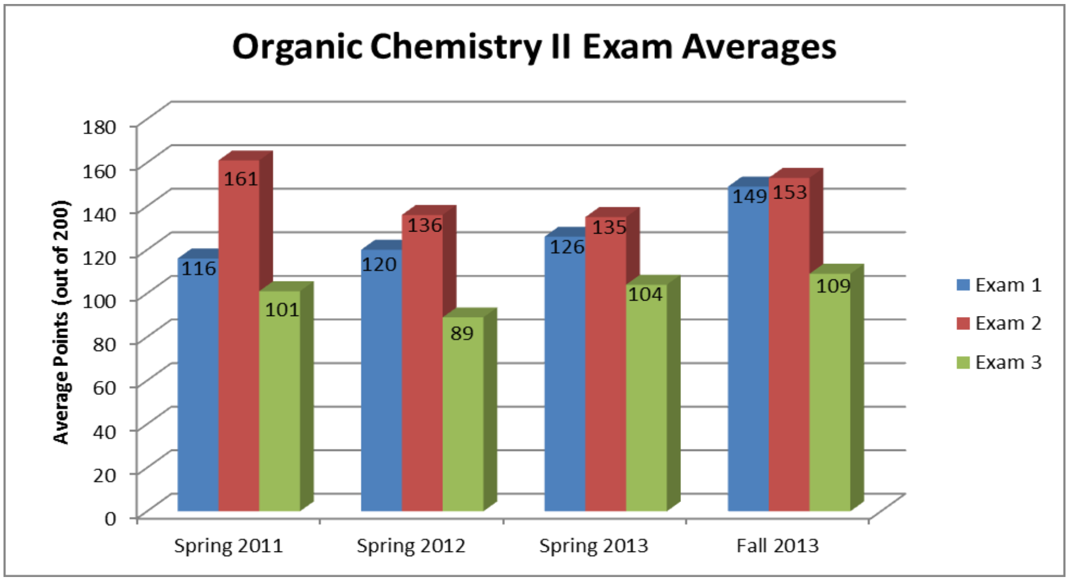


Figure 6 - Student examination averages out of 200 points for two semesters traditional (Spring 2011 and Spring 2012) vs. two semesters of inverted classroom organic chemistry I classes (Spring and Fall 20113).

Figure 7 illustrates the impact on the student averages of total semester points for organic chemistry II during these same semesters. Although more semester data is needed in order to see a trend, notable is the marked improvement observed for the Fall 2013 inverted class.

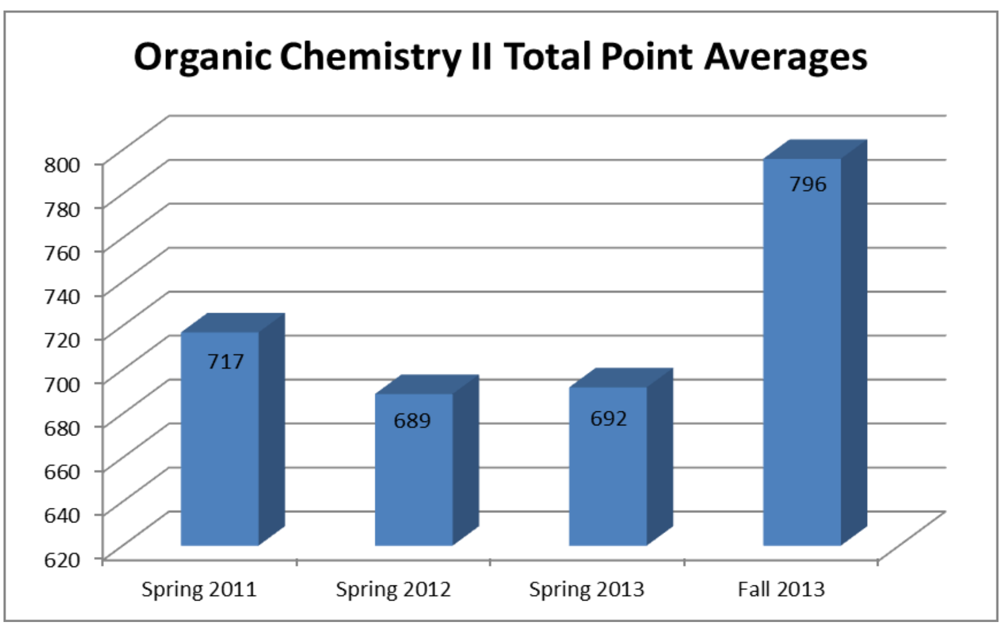


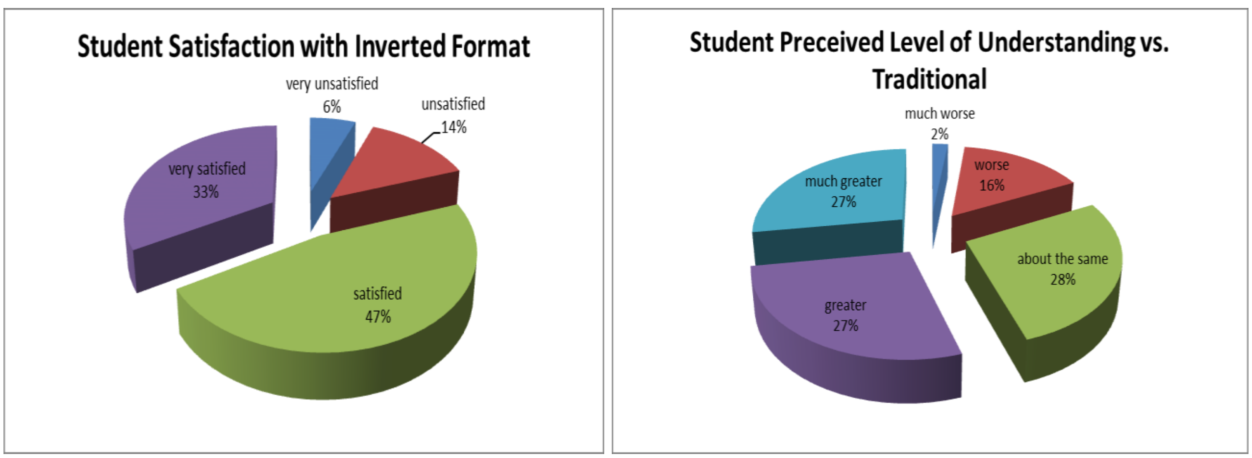
Figure 7 - Student total semester point averages out of 1000 points for two semesters of traditional classes (Spring 2011 and Spring 2012) vs. inverted classroom (Spring and Fall 2013) organic chemistry II classes.

Student Survey and Comments

At the end of each of the semesters where the classroom was inverted the students answered a questionnaire/survey designed to judge their overall satisfaction with the course, how they perceived what they learned relative to what they would have learned had the class been taught in the traditional format and how this format helped generally, with the study of organic chemistry. What is presented here is a compilation of the survey results for all semesters of the inverted classroom.

<u>Organic Chemistry I</u>

As figure 8a shows 80% of the students responded they were either satisfied or very satisfied with the inverted classroom format. Furthermore, 54% of the students perceived that their level of understanding of organic chemistry was greater or much greater than had this course been presented in the traditional format (figure 8b). Twenty-eight percent felt it would have been about the same as the traditional.



a b

Figure 8 – Organic chemistry I student satisfaction with the inverted course format (a), and (b) perceived level of understanding vs. the tradition format.

Overall 94% of the students reported that the inverted classroom format either somewhat or significantly helped them with the study of organic chemistry (figure 9), with the remaining 6% reporting that this format did not help at all.

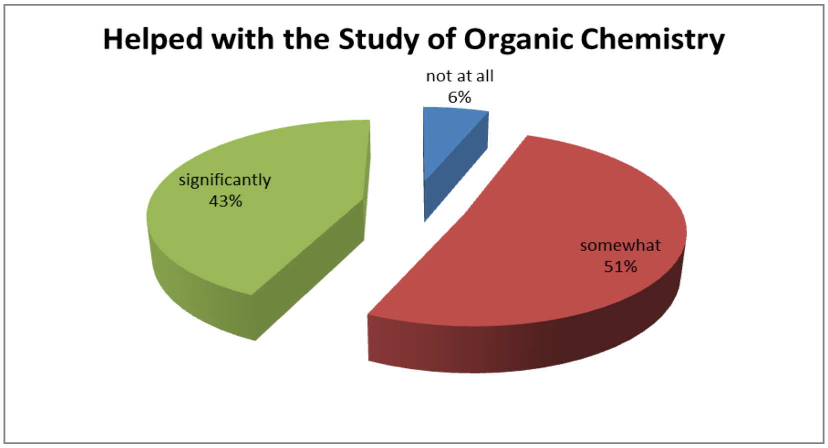


Figure 9 – How organic chemistry I students felt the inverted classroom format helped with their studies.

Figure 10 summarizes how the students felt about both the level of difficulty and number of the in-class problems. Eight-seven percent responded the level of difficulty of the in-class problems were about right while the remaining 13% were split between being too difficult and too easy (figure 10a). As shown in figure 10b 91% of the students felt the number of in-class problems reviewed were about right with only 9% feeling there were too few reviewed.

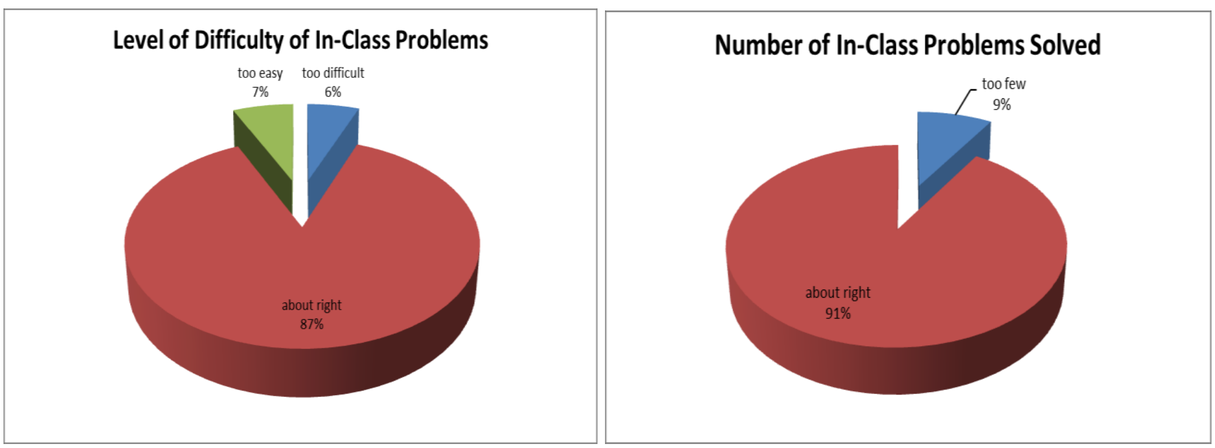


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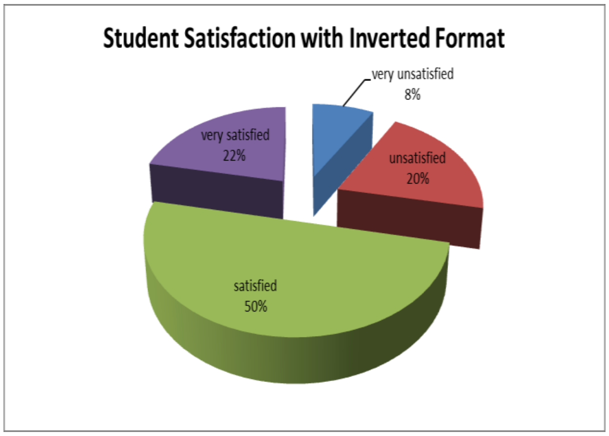
Figure 10 – Organic chemistry I students response to (a) level of difficulty of the in-class problems, and (b) number of problems solved during class.

Organic Chemistry II

Similar to organic chemistry I, the vast majority of organic chemistry II students (72%) were either satisfied or very satisfied with the inverted format (figure 11a). Forty-eight percent of the organic chemistry II students perceived their understanding of the subject to be either greater or much greater than if the class were traditionally taught while 30% claimed it to be about the same (figure 11b).



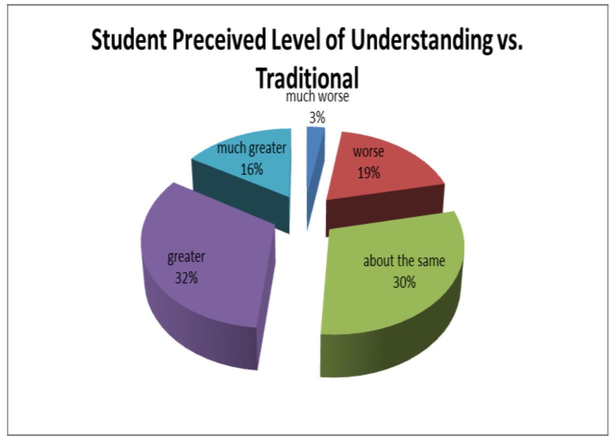


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Figure 11 – Organic chemistry II student satisfaction with the inverted classroom format (a), and (b) perceived level of understanding of the subject matter.

Eighty-four percent of the students (figure 12) reported this inverted format either helped significantly or somewhat with their study of the subject with only 16% reporting that it did not help them at all.

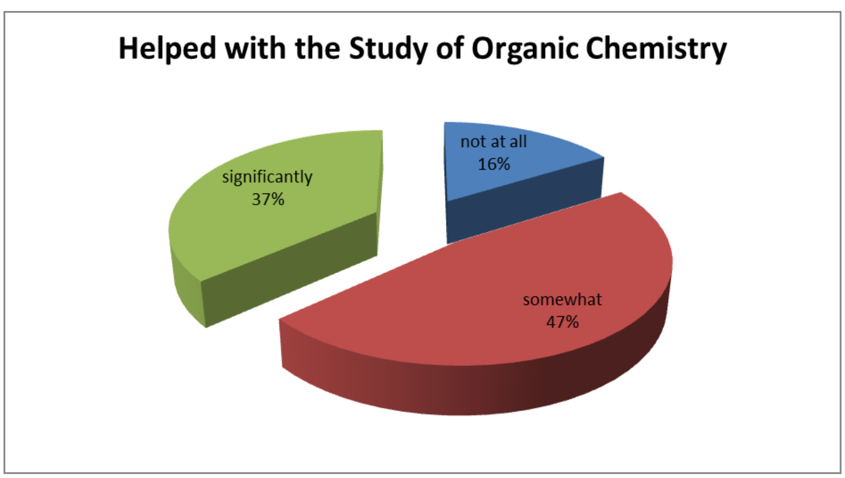
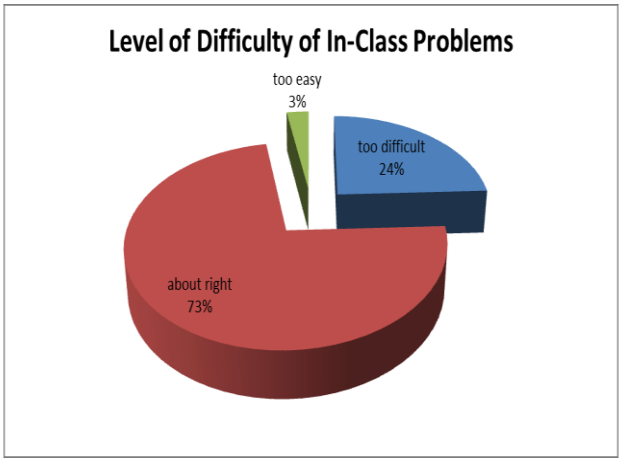


Figure 12 – How organic chemistry II students felt the inverted classroom format helped with their studies.

Figure 13 summarizes how the students felt about both the level of difficulty and number of the in-class problems. Seventy-three percent responded the level of difficulty was about right while 24% felt the problems were too difficult and 3% too easy (figure 13a). Figure 13b shows 78% of the students felt the number of in-class problems used was about right with 16% feeling there were too few reviewed and 6% too many.



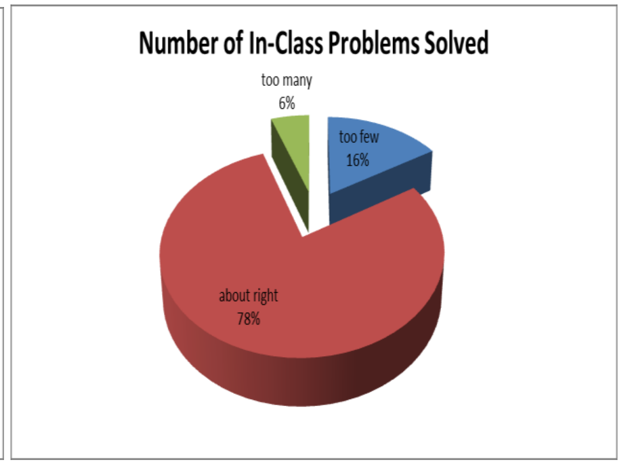


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Figure 13 – Organic chemistry II students response to (a) level of difficulty of the in-class problems, and (b) number of problems solved during class.

Student Comments

Table 3 gives a sampling of the typical student comments that were submitted as part of the end of semester survey.

Table 3 – Sampling of student comments on the inverted classroom format.

Student Comments – Organic Chemistry I
Lectures on demand - top notch! Professor spent a lot of time trying to simplify course. Very good professor!
The lectures on demand were useful, and I suggest that they should be kept up for future students.
Very helpful video lectures. Clear, understandable teaching style. Extremely organized
Any chemistry course is tough enough as it is. However the video lectures, coupled with in class problem sets have made it easy for me to learn. I can't imagine taking this course any differently now.
The online videos were difficult at first but turned out beneficial towards test time to study.
Love the video's, they were great! I really enjoy this course a lot. Can't wait from Organic II next semester.
Student Comments – Organic Chemistry II
The style and format of this course this semester was very helpful. I was able to look back at videos as well as compare with the text. It helped me with the problems and exams.
Great course. I really liked the online lectures. It helped me to better understand and learn the material. Also doing homework in class helped better understand the reactions.
The on-demand lectures were a great idea because you could re-watch them as many times as necessary. The in-class problems were a huge help because they are very similar in style to the test questions.
The video format used this semester was definitely effective and a nice change.

Conclusions

Although the financial investment required to invert your classroom is minimal, the investment in time is significant particularly if you decide to create your own video lectures, although once created are well worth that investment. The alternative is to invert your classroom using videos from outside sources like the Khan Academy (24) for all or part of your course. Although this does relieve the burden of having to produce the videos yourself, the tradeoff, many times, are topics not presented in just the way that corresponds to your teaching style or how you prefer your students learn the subject matter.

From the work presented here there are sufficient encouraging signs that support continued use of the inverted classroom model for both organic chemistry I and II. The rise in both exam score averages and total semester points for the last three semesters of organic chemistry I are believed to be significant and real. Although the amount of data for only two semesters of organic chemistry II is not conclusive, a positive trend is emerging. And anecdotally the vast improvement in student engagement in the subject for both semesters of the course as witnessed by student involvement in the collaborative/peer learning exercises that now are part of the classroom face-to-face time is extremely exciting to watch.

Finally it is important to recognize the inverted classroom, like other pedagogical innovations that are intended to improve student performance and engagement, is not the magic solution to all learning. If the students are not willing to spend the time required studying the video lectures and taking extensive notes they will be lost during the classroom activities, and quickly become frustrated with the format. Some students will even resent the time now required to watch the videos outside of class, mistakenly suggesting that amount of time was never required of them from the traditional format. Hence it is important to continually find ways to encourage students to stay current with the lecture videos as they are assigned.

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