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Upside Down Chemistry at Carolina

A transformation is sweeping chemistry education in Carolina's large lecture halls. The old paradigm of "chalk on rock" – a room full of silent undergraduate students taking notes while the professor lectures -- is being supplanted by dynamic and interactive high-structure learning environments. In these transformed classrooms, students grapple to understand tough concepts by working problems together, rather than trying to absorb the instructor's perspective.

Unlike traditional lectures, high-structure classes are active dialogs: classroom response systems (handheld electronic transmitters commonly called clickers) allow faculty to pose questions in real time and receive instant feedback from students. Students work on questions individually or in groups, and faculty members can then evaluate student understanding and adapt class content accordingly.

A wealth of educational literature shows that high structure learning provides educational gains for students. In particular, these methods have been shown to increase student engagement, promote development of higher-order cognitive skills, and create a more equitable learning environment. A growing body of research now promotes unique high structure environments called flipped classrooms, in which students attend to much of the would-be lecture content outside of class (either by textbook readings or by watching brief mini-lecture videos) and spend the majority of their in-class time applying this knowledge to challenging practice problems.

In the fall semester of 2012 the authors of this article undertook a project to transform their sections of Chemistry 101 into flipped classes with a small grant from the UNC Center for Faculty Excellence. Before each class, students were directed to instructional videos and textbook readings that introduced content, and in-class clicker quizzes at the start of each class were used to verify completion of these assignments. An online homework system provided pre-lecture tutorials and post-class self-tests. Roughly 50% of the class time that would formerly be used for lecturing was then dedicated to individual and group problem-solving exercises. In addition, a cadre of experienced undergraduate students served as in class learning assistants, or "peer mentors." Often chemistry majors, these successful graduates of the class roved between student groups to aid and instruct student working groups.

Preliminary results show that flipping General Chemistry is improving student learning AND making for a more positive class experience at Carolina. Comparing to benchmark past years of instruction (controlling for semester and for instructor), the following was observed:

Learning improved: Overall student performance on a nearly identical final exam improved from a mean score of 69% to one of 77%.

More students were empowered to continue in chemistry: Preliminary analyses suggest that, while grades were comparable in the two classes (a

roughly 0.05 GPA boost was seen in the flipped class), a substantial gain was seen in the number of students earning grades of C- or above (the threshold for grade for entry into chemistry 102). Students completing the flipped class met this mark at a rate of 81%, while 76% did so in the traditional lecture format.

Student learning is less heterogeneous: Distributions of final exam scores in the flipped class show a relatively "normal" (aka Gaussian) distribution (Figure 1). This is in contrast with the apparently bimodal grade distribution observed in previous semesters and in most entry-level large lecture format classes. These data suggest that the flipped class offers a more equitable learning envrionment – ameliorating, rather than accentuating, differences in student college preparation.

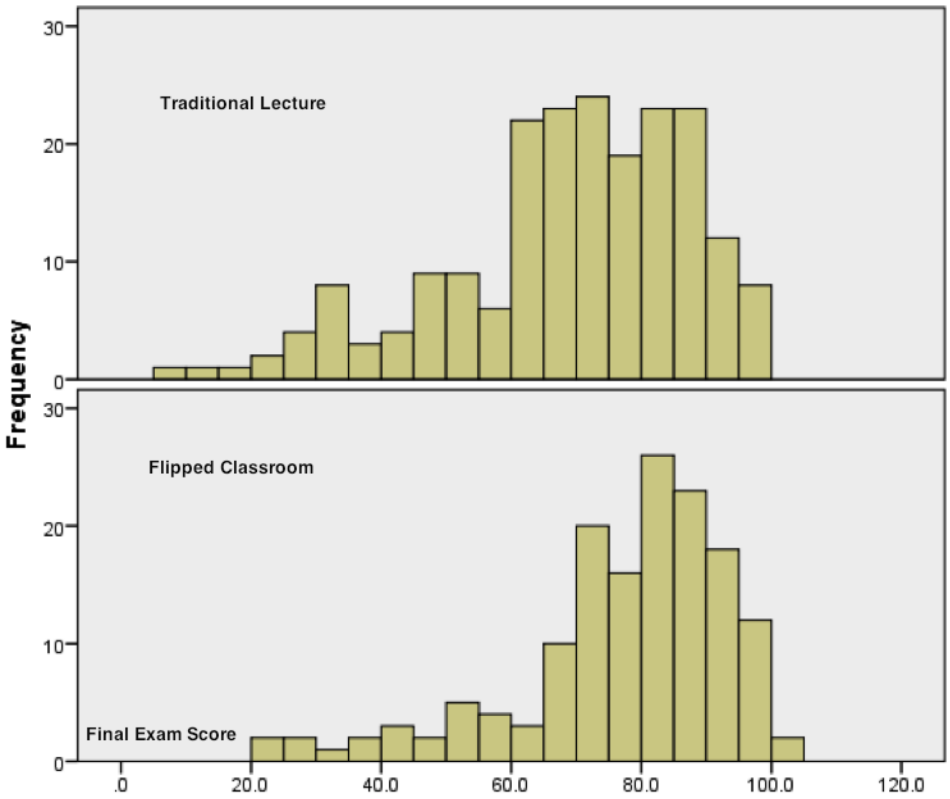

Figure 1: Scores on nearly identical final exams in traditional versus flipped format classes.

Students report higher levels of engagement. Comparing student end-of-semester Faculty Course Questionnaires before and after the flip revealed improvements in the items "instructional techniques engaged me", "instructor provided me with helpful feedback", "instructor used class time well", "instructor encouraged students to participate in class" AND "course was designed to keep me engaged in learning". Similar feedback was obtained in a focus group interview:

"...you can grasp a concept by reading it; but it is like, once you sit there and do it and have it worked out for you is when it actually sinks in. So I like it."

"I think I learned a lot more in this type of chemistry class because I know if being... [pause]. It was an early class, if she was just talking straight for a long time, especially [in] this class you have to solve problems on the test in order to do well. So practicing solving is great instead of her just going through them ... We are actually doing them and talking to other people about them. It lets you become more engaged because you are actually doing them on your own."

"And the quizzes are like incentives to actually read and try to learn the materials as much as you can before you actually come to class. … I like the format of the PowerPoints and doing those, and doing problems to re-iterate everything we learned outside of class."

As an extension of this effort, Carolina's Organic Chemistry sequence is currently undergoing a similar transformation. Funded by a $500K campus-wide grant from the Association of American Universities (a fundraising effort led by Prof. Mike Crimmins, Chemistry), clickers are being deployed in the Organic Chemistry I lecture halls this semester, and students have been given access to a storehouse of instructional videos. Preliminary results from the first midterms in all Organic sections are extremely encouraging, suggesting not only significant learning gains but also increases in educational equity. Future efforts in the department will include redesign of the second semester Organic and General Chemistry courses.

- Dr. Jen Krumper and Ms. Carribeth Bliem