Research-based active learning in introductory physics: SCALE-UP Physics

CTL Fellows 2013-14 Final Report

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Physics education research has consistently shown that the teaching strategies which are most effective are those which foster interactions between students in the classroom. This research has also clearly shown that the traditional lecture is a much less effective means of furthering student understanding in physics than are hands-on "active" learning activities which requires students to think and respond in class, rather than to sit quietly and take notes.

In the Physics Department at Trinity, our introductory calculus-based physics courses have had, until now, a standard "science class" structure, with three 50-minute lecture sections and one afternoon laboratory every week, quite typical of physics programs throughout the U.S. And while many of us have introduced activity-based classwork into our courses, the overarching format remains that in which most attention is focused on the instructor. In the laboratory, our students carry out experiments carefully designed to illustrate important physical principles and teach laboratory technique. Yet despite having invested a good deal of effort on the laboratory experience, we are left uneasy with the feeling that, on average, students are too passive in the lab, too willing to simply follow directions without having to think deeply enough about the underlying physics

These concerns, and others, are echoed at many other institutions. For instance, the percent of physics degrees earned by women nationwide has remained stalled at just over 20%; African Americans make up only 3% of physics bachelor's. Statistics within our own department are quite similar. We want to do more to retain women and minorities. We would also like to increase the overall number of majors in the department.

To help achieve these goals, the Physics Department has decided to introduce a new teaching model into our first-semester introductory physics course starting in the Fall semester of 2014. The changes we plan to make will entirely restructure both our laboratory and lecture.

The pedagogy we intend to apply is known as SCALE-UP (Student-Centered Active Learning Environment with Upside-down Pedagogies), a research-based initiative originating with the North Carolina State University physics education research group[i]. This method replaces the weekly lectures and afternoon laboratory with three two-hour sessions in a classroom specially designed to promote interactions. Students work in carefully-structured groups at large round tables using experimental equipment, computer visualization, computer modeling, and other strategies to solve problems and explore physical principles in an inquiry-based setting. Students spend most of their time thinking, explaining, and doing, rather than taking notes. They collaborate with members of their group at large whiteboards lining the room and on computers and smaller whiteboards at each table, and make use of large display screens about the room to present their work. The instructor no longer lectures from behind a desk, but circulates about the classroom assisting students, asking and responding to questions, and occasionally delivering a short mini-lecture used mainly to motivate, to facilitate discussions of what students have discovered through group work, and to draw connections between topics. In a traditional setting, students listen to lecture in the classroom, then struggle with concepts outside the classroom, on their own, when they do homework. With SCALE-UP, that struggle will happen inside the classroom, where students can get immediate feedback and guidance.

This kind of teaching takes more time than traditional lecturing, and we get that by merging lab and lecture time together; the total amount of time that students will spend in class is unchanged, but, we hope, better distributed.

We became convinced to adopt this model because of the impressive learning gains demonstrated by students enrolled in SCALE-UP classes compared to those in traditional, non-interactive lecture/lab classes[ii]. Studies involving thousands of students show both a twofold increase in conceptual learning among SCALE-UP students, as measured through their performance on standardized conceptual tests, and an increase in their problem-solving ability. Most impressively, the D/F rates (grade lower than C-) of women and of minorities, groups traditionally underrepresented in physics, drop by factors of 4 and 3 respectively. And the data show that it is not just lower-performing students who gain; rather, it is students in the top third of the class who demonstrate the greatest improvement in conceptual understanding. Additionally, students who take a SCALE-UP course in their first semester of physics exhibit improved performance in their second semester of the introductory physics sequence as well, even if it is taught as a traditional lecture course.

We will apply the SCALE-UP approach to the first semester of our introductory calculus-based physics sequence (Phys-141 - Physics I: Mechanics), starting this coming semester, Fall 2014. This course typically has enrollments of just over 60 students; every student who majors in physics, engineering, chemistry, and biochemistry is required to complete the course, so the adoption of SCALE-UP will impact students across the sciences, not just those in physics.

SCALE-UP seems to “work” because it fosters strong collaborative relationships between individual students, within the class as a whole, and between the students and their TAs and faculty instructors. This emphasis on interaction means that adoption of SCALE-UP will require not just a change in the curriculum, but a change in the classroom space, one specifically designed to support and encourage this type of behavior.

Fig. 1: McCook 106 – typical introductory physics classroom

Fig. 1, above, shows why it is difficult to teach a hands-on interactive course in a typical introductory physics classroom. Space is tight, students can talk only to their immediate neighbor, and the instructor can interact directly only with those students on the periphery of the room. There is little space for any kind of experimental work. Students have difficulty seeing all of the board space, and one full quarter of the room is taken up by the instructor's bench and work area.

The Physics Department has dedicated McCook 219, one of our laboratory spaces to be our new SCALE-UP classroom; this summer the teaching space will be completely renovated, as shown in Fig. 2. Students will be able to work with their groups at the large tables or work problems at the wall, which will be completely covered with a writable whiteboard surface. Multiple projectors will be used for display, so that even with circular tables every student will have a good sightline. Backpacks and phones will be tucked away at the back of the classroom to make it easy for students, TAs, and the instructor to circulate about the room. Each group has a laptop, which they can use for data collection, gathering information from the web, or accessing class material – but because it is a laptop it can easily be shut when not needed, to reduce distractions. There is no longer a "back of the classroom" where disengaged students can hide, or a "front of the classroom" for instructor only.

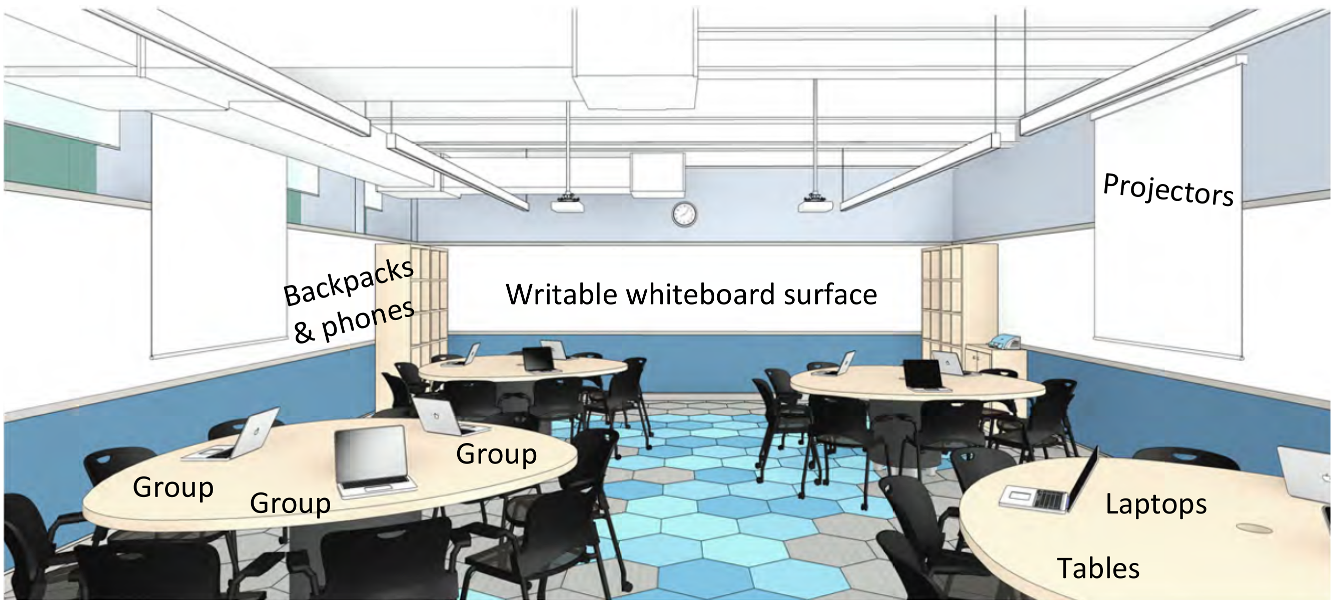

Fig 2: McCook 219 – renovated as a SCALE-UP classroom

Dozens of educational institutions of all sizes have adopted SCALE-UP: North Carolina State University, MIT[iii] (where it is implemented under the name "TEAL"), Cornell, Yale, Ithaca College, and many others. Its use has spread beyond physics to biology, chemistry, math, and other fields. Among our peer schools, we believe we will be the first to implement this pedagogy.

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[i] North Carolina State University SCALE-UP website: http://scaleup.ncsu.edu/

[ii] The Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) project, *R. J. Beichner, J. M. Saul, D. S. Abbott, J. J. Morse, D. L. Deardorff, R. J. Allain, S. W. Bonham, M. H. Dancy, and J. S. Risley* http://www.per-central.org/per_reviews/volume1.cfm

[iii] http://icampus.mit.edu/projects/teal/