Introductory Astronomy Student-Centered Active Learning at the George Washington University

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Abstract. The Physics Department at the George Washington University has been successfully using student-centered active learning (SCALE-UP) in physics classes since 2008. Recently (since fall 2011), we have been developing and implementing introductory (non-majors) astronomy classes taught in the student-centered active learning mode. Class time is devoted to engaging in hands-on activities and laboratories and tackling questions and problems in a workbook. Students work in small groups, and multiple instructors circulate to answer questions and engage students in the material. Research has shown that students who are engaged in this manner have an increased conceptual understanding of the material. In developing our “Stars, Planets and Life” course into an interactive class, we encountered many challenges, but there have also been positive outcomes. Improvements to this class are ongoing, and in fall of 2013 we will begin full implementation of SCALE-UP in our “Introduction to the Cosmos” course.

1. Introduction

At the George Washington University, the goal of astronomy classes is not just for students to memorize facts but also to learn how to think logically and analytically, to understand the process of modern astronomy, and to appreciate how we know what we know about the Universe. These goals clearly call for making the students think and act like scientists whenever possible. To this end, in fall 2011, we implemented a section of our “Stars, Planets and Life” course in full SCALE-UP (Student Centered Active Learning Environment—Undergraduate Program)\(^1\) mode. Having students take an active role in their learning can be challenging, as it requires more commitment, creativity, and in-class brain power than a traditional introductory lecture class. However, research has shown that students who are engaged in this manner have an increased conceptual understanding of the material and are better able to solve problems. Here, I describe our methods, our successes, and our challenges of integrating active learning into a non-majors introductory astronomy course.

\(^1\)www.ncsu.edu/per/scaleup.html
2. Active Learning Classroom

In SCALE-UP, class time is devoted to engaging in hands-on activities, laboratories, simulations, and interesting questions and problems. Students work together in small groups to gain a deeper understanding of the material. Multiple instructors (professors and TAs) circulate to answer questions and engage students in additional contemplation of the material. Lecturing is kept to a minimum. Typically, several five to ten-minute mini-lectures are interspersed throughout the class time—used only when extra introduction or clarification is necessary. Students are expected to come to class with a working knowledge of the material and are given a short quiz on the textbook material each week to motivate pre-class reading.

The special SCALE-UP classroom at GW holds up to 81 students. Classes meet for two hours twice a week. The students are seated in three groups of three students around large round tables (see the image below). The classroom is equipped with projectors or monitors on each wall, so that students can see PowerPoint slides or videos from any seat. Note the classroom has no clear position from which the instructor can comfortably lecture!

![Figure 1. GW’s SCALE-UP classroom. Each table holds nine students (typically three groups of three students). Almost every wall is a white board that students can write on.](image)

3. Active Learning Methods

In fall 2011, students answered questions and problems displayed via PowerPoint slides in a special lab notebook; each page had a “carbon-copy” sheet that was collected for grading. Because the questions and answers were separate, however, students had trouble reviewing their work for exams. Students also had little incentive to correctly and fully answer the questions because we did not have the manpower to thoroughly
Figure 2. Example SCALE-UP workbook page. In-class work and homework is meant to prepare students for exam questions that probe their understanding and ability to work through a problem rather than rote memorization of facts.

grade the 20+ answers written by 60+ students per week. This format also gave the students almost no incentive to work with each other in their groups.

Inspired by Ed Prather et al.’s Lecture Tutorials for Introductory Astronomy, the questions for spring 2012 were consolidated into a class workbook (see example below), which has been used each semester since. To simultaneously simplify grading
and give the students an incentive to work together, each week only one workbook is collected and graded per group. This workbook is chosen at random—so the students do not know ahead of time whose workbook will be graded that week—and all students in the group receive the same grade based on that work.

Workbook questions come in many types, including straightforward definitions and explanations of basic phenomena and summary charts requiring students to compare and contrast various phenomena. The workbook also contains equation-based calculations for students to complete. Other questions touch on higher cognitive levels by requiring students to apply factual knowledge to novel scenarios. In particular, questions of this type often asked students to “imagine that…” or explain “what would (or might) happen if…” Additionally, the workbook makes students “think like a scientist” by asking students to identify the data required to answer a question, draw conclusions from data, or identify sources of error and uncertainty.

In addition to the workbook, clicker questions are used to challenge students individually. To further peer-learning, clicker questions with low correct response rates are re-pollcd after a table-wide discussion—usually resulting in a significant increase in correct answers.

Some of our active learning class time is also devoted to hands-on and kinesthetic activities as well as computer simulations and more traditional laboratory exercises.

4. Successes

Many students like the interactive format and find it beneficial to their learning. Some groups become very close-knit and study together outside of class. In the course evaluations, students make very positive comments such as: “I really enjoyed the course, it got me excited about astronomy, rekindling my old passion for the subject. The SCALE-UP format was also extremely conducive to learning, and was especially effective for non-science majors and those who wouldn’t normally excel in a science course.”

In spring 2012, two sections of ASTR 1001 were taught: one SCALE-UP and one “traditional” lecture. Interestingly, one of the most positive effects of SCALE-UP was on the low end of the grade scale. In SCALE-UP, only 4% of the class scored a D+ or lower compared to 15% in the lecture section. This is anecdotal evidence only, however. One possible explanation is that students who would not have performed well are “scared away” from the SCALE-UP section during drop/add period by the level of commitment and interactively mandated by the course. In the future, we hope to examine in detail the performance of students in the different sections to measure the effect of interactive learning on non-science majors at the George Washington University.

5. Challenges

5.1. Leadership Structure

In fall 2011, the student-centered section of ASTR 1001 was team taught by three professors and a TA. While this collaboration was beneficial in building the class from the professors’ point of view, the presence of so many instructors in the classroom was extremely confusing to the students. And sometimes because the instructors had not communicated well enough with one another prior to class, we would accidentally give students inconsistent answers about due dates, grades, etc. The obvious solution to
this challenge is to provide the students with a clearer sense of who is in charge of each portion of the class and to be completely consistent about class issues. Since we began clearly defining for the students the roles of each instructor in the classroom, the problem of an unclear leadership structure has completely disappeared.

5.2. Distractions

In fall 2011, we allowed laptops but not cell phones in the classroom. Unfortunately, we were not strict about the cell phone ban during the first weeks of class (when class habits are set), and the cell phone situation quickly deteriorated. Non-class related Internet activity on laptops also became a clear problem. With no need for extensive note-taking, the solution in spring 2012 was to ban both laptops and cell phones and to consistently enforce this policy. Exceptions were allowed for students with a legitimate need (and who were willing to sign a “laptop use agreement”), but very few students requested exceptions. We have successfully continued the policy of a “distraction free” classroom, and it makes for a much more focused and engaged classroom.

5.3. Group Dynamics

Possibly the most challenging issue is that of group dynamics. While some groups worked extremely or moderately well together, a number of groups never become truly cohesive. In those groups, students just answer questions individually—with almost no group discussion. Making the individual grades dependent on the group helped to increase group cohesion, but did not solve the problem entirely. Due to the administrative hassle, in the first few semesters the groups were not altered at any point during the semester. Starting in fall 2012, we have opted to change the groups two or three times per semester. While this, unfortunately, does break up cohesive groups, it also means that students encounter a wider range of partners over the semester. Hopefully this means that no student is trapped with a non-communicative group for the whole semester.

5.4. Not For Everyone!

SCALE-UP is not for every student. Some students would prefer, and may do better, in a traditional lecture. Students should be clearly informed of what will be expected of them (in addition to the possible benefits of the SCALE-UP format) both in the course description, course syllabus, and during the first few days of class. This gives students the information they need to “opt-out” early on if the class is not a good fit for them (plus, of course, the opportunity to opt-in if they like the idea!).

6. Conclusions

SCALE-UP in George Washington’s introductory astronomy courses remains a work in progress. Each semester, we strive to learn more about what does and does not work, and to respond to student feedback. We continue to improve our implementation of an active classroom in “Stars, Planets and Life.” In fall of 2013, we will also begin full implementation of SCALE-UP in our “Introduction to the Cosmos” course. Despite the challenges associated with SCALE-UP, we strongly believe that our students are benefiting intellectually by being engaged in the classroom and hope that these students walk away with a deeper appreciation of the Universe around them.
Acknowledgments. This work is entirely the result of a collaboration with fellow George Washington ASTR 1001 SCALE-UP instructors Carol O’Donnell, Peter Hahn, Paul Butterworth and Rob Coyne. B. E. Cobb thanks them wholeheartedly for their support, wisdom, patience, and humor!