Creating a Student-Centered Collaborative Learning Environment in a University Physics Classroom

Gerald FELDMAN (1), Guillaume SCHILTZ (2)

(1) Department of Physics, George Washington University, Washington, DC, USA
(2) Department of Physics, ETH Zürich, Zürich, Switzerland

Abstract. An active-learning workshop is offered to provide an example of a collaborative group-learning pedagogical environment for introductory physics at the university level. Participants will engage in various hands-on and minds-on exercises to illustrate how such a dynamic classroom can transform the strategy for teaching physics in university classes. A discussion about the benefits and challenges of this innovative approach will help guide the participants in adopting this teaching methodology in their own physics classes. We are working to establish a network of pedagogical innovators among the participants so that this type of approach can be more widely disseminated.

Background and Motivation

The time-honored conventional lecture ("teaching by telling") has been shown to be an ineffective mode of instruction for introductory physics classes. For enhancing critical thinking skills and developing problem-solving abilities, collaborative group-learning environments have proven to be far more effective. Reducing dropout rates, promoting conceptual understanding, and enhancing student engagement are the major successes reported in the PER literature [1-3].

At George Washington University (GWU), we started implementing a collaborative group-learning pedagogical approach known as SCALE-UP [4] for the introductory physics classes in 2008. Since 2013, the entire introductory physics sequence has been taught exclusively in this mode, eliminating the "standard" lecture format, and this approach has been demonstrated empirically to yield higher gains in student learning [5]. This approach was also implemented on a trial basis at ETH Zürich in the Spring 2017 semester, and the results for the collaborative class were shown to be superior compared to those for a parallel lecture class [6].

SCALE-UP is a large-class (~100 students) active-learning approach that engages students in groups at all times. It is intended to be used in the class sessions for all of the students together, and it is not relegated only to tutorial or recitation sessions that are led by Teaching Assistants. The SCALE-UP classroom is completely directed by the primary instructor, and in that regard, all of the students receive a consistent exposure to the in-class activities and subsequent discussions. In the SCALE-UP methodology, students typically sit at large round tables in three groups of three. The students work collaboratively in their groups to carry out a wide variety of pencil/paper exercises (ponderables) involving conceptual or numerical problems using small whiteboards and to engage in hands-on activities like demos and labs (tangibles) throughout the class period. Direct instruction (*i.e.* formal lecture presentation) is reduced to a minimal level and the instructor serves more as a "coach" to facilitate the academic "drills" that the students perform.

This innovative pedagogy often arouses the curiosity of physics faculty, who wonder how the small-group format is organized and what physics activities constitute a typical class session. Two short examples of such group activities are given below.

- Ponderable: Students work together on a problem that can be easily solved by conservation of energy (*e.g.* "If a 5 kg block slides down from the top of a frictionless hill that is 20 m high, how fast will the block be moving at the bottom?").
- Tangible: Students place a beaker of water on a scale and then predict/determine the scale reading when a metal block is submerged in the water while suspended from a string.

The workshop will provide further examples that can be implemented in your own classrooms.

Workshop Activities

This workshop will be an active-engagement experience for all participants. We will begin with an introduction to student-centered learning environments and discuss the challenges and possible drawbacks that can arise, in contrast to typical physics lectures. Participants will then work together on various exercises covering topics from mechanics to electromagnetism to illustrate the possible range of physics group-learning activities suitable for calculus-based introductory courses. The focus will be on the in-class delivery of the exercises and the pedagogical value of the collaborative activities. Our aim is for participants to experience this from the student perspective, which is useful in order to fully appreciate the benefits of interactive engagement. Workshop activities will include:

- Clicker questions using an electronic response system
- Whiteboard exercises comprising conceptual or numerical problems
- Group quizzes using "lottery ticket" scratch-off cards
- Short hands-on exercises involving tangible manipulation

Finally, we will invite a broader exchange and sharing of experiences from all participants and conclude with a discussion about possible schemes for further networking.

During the workshop, there will be time for questions and discussions, which are highly encouraged in an active-learning environment. The workshop will be completely flexible, and the emphasis can vary depending upon the preferences of the participants. We hope to demonstrate the feasibility and advantages of the collaborative group-learning approach and to inspire the workshop participants to consider their own implementations in their local institutions.

Conclusion

The objective of this workshop is to provide a clear and impactful example of the dynamic atmosphere that can prevail in a physics class conducted using such a collaborative group-learning approach. Workshop participants will learn how to develop and implement various hands-on and "minds-on" activities for their students in a collaborative pedagogical approach. Having the participants themselves play the role of "students" in this environment will help convey the real sense of teamwork and group dynamics that is brought to bear in such a classroom. With this background, participants will be well prepared to identify the benefits of the method and to deal with the potential challenges that can arise when adopting an active-learning approach at their own institutions. The materials that will be used in the workshop can also be shared with the participants if they wish to use some of these resources in their own classrooms. We hope to establish ongoing connections with workshop participants that can be leveraged even after the time of the conference.

References

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