Student-centered active learning strategies for instruction and assessment in large-enrollment physics courses

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Abstract. Under the leadership of the Carl Wieman Science Education Initiative, large-enrollment physics courses at the University of British Columbia were transformed under the umbrella of a scientific approach to teaching, using a variety of student-centered active learning strategies. In this talk, we will present on these strategies, highlighting the effort required to implement and sustain each learning strategy. These strategies are development of course learning goals; pre-class preparation assignments; in-class group-work via the use of Peer Instruction with clickers and worksheets; collaborative group-work in recitations/tutorials, online homework with feedback; collaborative group components in tests; frequent testing; and test correction assignments.

1 Background and Motivation

Starting in 2007, physics courses at the University of British Columbia (UBC) started undergoing systematic transformation toward adopting a scientific approach to teaching under the leadership of the Carl Wieman Science Education Initiative (SEI). The four-step process for course transformation [1] that has guided course transformation under the SEI has been to (1) establish what students should learn; (2) measure scientifically what students are actually learning; (3) adapt instructional methods and curriculum and incorporate effective use of technology and pedagogical research to achieve desired learning outcomes; and (4) disseminate and adopt what works. Although the exact approaches adopted varied from course to course, the majority of large-enrollment physics courses at UBC adopted, and continue to use, student-centered active learning strategies. More recently, a meta-analysis [2] has demonstrated that courses taught using student-centered active learning strategies lead to improved learning over courses taught using a conventional lecture approach.

2 The Instructional Strategies Used in a Typical Large-Enrollment Physics Course at the University of British Columbia

Although implementation details vary from course to course, a common collection of instructional strategies have been adopted by most large-enrollment physics courses at UBC. These strategies are summarized throughout the rest of this section.

We developed and communicated to the students, complete sets of course learning goals [3]. These learning goals provide the criteria against which to measure what the students are learning, but also guide the students' in their own learning efforts in the courses.

We use pre-class preparation assignments ("pre-reading") [4, 5] in order to provide the in-class time needed to use the active learning strategies. They also provide the added benefit of giving students with diverse learning needs the resources and time required to arrive in class ready to participate productively in the student-centered learning activities.

In-class time is spent mostly performing work in small groups via the use of the Peer Instruction ("think-pair-share") instructional strategy with clickers [6] and with custom worksheets designed specifically for each course. Mini-lectures are used to lead into or debriefing the group learning activities. Additional group-work is present in the supplemental contact hours, such as recitations/tutorials.

The courses use online homework with feedback (such as Mastering Physics [7], WebAssign [8], etc.). Some courses additionally ask for a small number of hand-written problem solutions throughout the term in order to help students develop skills related to the formal presentation of problem solutions.

The reform efforts also impact our testing strategies. Almost all courses include a collaborative group component to their tests [9], which provide students with immediate feedback on the test as well as a further opportunity for learning. Some courses use frequent testing [10], a strategy that encourages students not to fall behind with their course work and which promotes additional student learning by an effect known as the testing effect [11], by providing students with additional opportunities to practice content retrieval and practice in applying concepts. Some courses also use test correction assignments [12], a type of exam wrapper [13] designed to provide students with structured opportunities to learn from their own mistakes.

3 Conclusion

In this talk, we will present a variety of student-centered active learning strategies in use in large-enrollment physics course at the University of British Columbia, highlighting the effort required to implement and sustain each learning strategy, as well as evidence regarding their effectiveness.

References

[1] *The Carl Wieman Science Education Initiative*, Retrieved from http://cwsei.ubc.ca/

[2] Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415.

[3] Simon, B., & Taylor, J. (2009). What is the value of course-specific learning goals?. *Journal of College Science Teaching*, *39*(2), 52.

[4] Heiner, C. E., Banet, A. I., & Wieman, C. (2014). Preparing students for class: How to get 80% of students reading the textbook before class. *American Journal of Physics*, *82*(10), 989-996.

[5] Stelzer, T., Brookes, D. T., Gladding, G., & Mestre, J. P. (2010). Impact of multimedia learning modules on an introductory course on electricity and magnetism. *American Journal of Physics*, *78*(7), 755-759.

[6] Mazur, E. (2017). Peer instruction. In *Peer Instruction* (pp. 9-19). Springer Spektrum, Berlin, Heidelberg.

[7] *Mastering Physics*, Retrieved from https://www.masteringphysics.com

[8] *WebAssign*, Retrieved from https://www.webassign.com/

[9] Gilley, B. H., & Clarkston, B. (2014). Collaborative testing: Evidence of learning in a controlled in-class study of undergraduate students. *Journal of College Science Teaching*, *43*(3), 83-91.

[10] Laverty, J. T., Bauer, W., Kortemeyer, G., & Westfall, G. (2012). Want to reduce guessing and cheating while making students happier? Give more exams!. *The Physics Teacher*, *50*(9), 540-543.

[11] Roediger III, H. L., Putnam, A. L., & Smith, M. A. (2011). Ten benefits of testing and their applications to educational practice. In *Psychology of learning and motivation* (Vol. 55, pp. 1-36). Academic Press.

[12] Henderson, C., & Harper, K. A. (2009). Quiz corrections: Improving learning by encouraging students to reflect on their mistakes. *The physics teacher*, *47*(9), 581-586.

[13] *Exam Wrappers,* Retreived from https://www.cmu.edu/teaching/designteach/teach/examwrappers/