Utilizing Teaching Assistants to Increase Student-Centered Learning in Lectures

Doga Yucalan[†], Celia Evans[‡], Lisa Schneider-Bentley[‡]
† Mechanical and Aerospace Engineering Department, Cornell University, Ithaca NY
‡ Engineering Learning Initiatives, Cornell University, Ithaca NY

Abstract

Students learn the most effectively when they construct and apply knowledge while interacting with their peers in the classroom. In addition, when students recall their thinking prior to an activity and compare it to that after the activity, they improve their metacognition and scientific thinking. While the desire to adopt such student-centered techniques into their lectures is common in faculty, the additional time commitment is a typical barrier. This work describes a pilot program called the "Interactive Learning Collaborative" that supports trained teaching assistants (TAs) in designing and implementing interactive activities and retrospective post-assessments in lectures, in partnership with faculty. The objectives of the pilot were to 1) provide engineering TAs opportunities to practice activity design and implementation, 2) improve students' comprehension of the material through peer interaction and reflection in lectures, and in doing so, 3) demonstrate to faculty these pedagogies and their positive impact on student perception. In the fall of 2021, TAs met with a mentor regularly to design activities and post-activity student reflection questions around topics that were either (historically) confusing or critical. The mentor worked with six TAs from four courses to design and execute 13 activities in total. Throughout the semester, 70–95% of students stated that their comprehension of the topic improved with peer interaction and reflection. Moreover, instructors who were previously inexperienced with student-centered learning mentioned feeling more confident designing learning activities and delegating the task to their TAs after this program. Anecdotal observations suggested that TAs became more confident and independent and the quality of their activities improved over time. Overall, this pilot improved TAs' skills and confidence, students' perception of their learning, and course instructors' exposure to student-centered learning strategies.

Introduction

The Differentiated Overt Learning Activities (DOLA) framework defines interactive learning activities as those in which students work with each other or with experts to sequentially or jointly construct knowledge in addition to what the instructor may provide [1]. Compared to other types of activities in the framework (constructive, active, and passive), interactive activities result in the highest cognitive gains among engineering students because they provide students with access to their partner's knowledge, scaffolding, and immediate feedback [2]. In like manner, retrospective post-assessments describe activities where students remember their understanding or thinking prior to a learning activity and compare it to that after the activity. These activities improve students' metacognition (thinking about their learning) by providing them the structure to reflect and recognize the improvement in their learning [3]. They further help students identify their strengths and weaknesses and employ skills to optimize their learning [4]. Consequently, increasing the number of interactive learning activities and retrospective post-assessments in the engineering classroom should increase students' learning gains.

Many college instructors state their desires to adopt such student-centered techniques into their courses. However, in many institutions, they do not get adequately trained or supported to improve their teaching [5] or adequately evaluated and rewarded for their efforts toward teaching effectiveness [6]. To address these issues while increasing students' learning gains in the classroom, we designed and piloted the "Interactive Learning Collaborative" in the fall of 2021. Under this program, teaching assistants (TAs) worked as interactive-activity and retrospective-post-assessment designers and facilitators with the help of an experienced TA mentor and in partnership with the course instructor and the program lead. The specific objectives of this pilot program were to, 1) increase TAs' skill and confidence in designing and implementing student-centered learning activities with formal mentorship, 2) help improve students'

comprehension of the course material by increasing peer interaction and reflection in the classroom, and 3) provide faculty with a low-effort way to incorporate more student-centered learning opportunities into the lecture portions of engineering courses while introducing them to pedagogical tools and strategies such as backward design, writing and sharing learning objectives, promoting student interaction, and promoting metacognition.

Methods

Program participants and course characteristics

Each of the participating four instructors taught a distinct, lecture-based engineering course in a distinct department, ranging from first- to third-year courses with 60 to 130 students in each. These courses covered topics in mechanical engineering, materials science and engineering, data science, and applied mathematics. Three of the instructors had minimal to no experience implementing student-centered activities in their classrooms. In contrast, one instructor had implemented regular group discussions as part of their lectures previously.

Five graduate TAs and one undergraduate TA participated in the program (each instructor chose one or two TAs from their course). All participating TAs had previously taken the mandatory TA training program offered by Engineering Learning Initiatives. This training program modeled and included evidence-supported pedagogies, including promoting inclusion in the classroom, active learning, group dynamics and management, and universal design for learning.

One experienced TA mentor (later referred to as "mentor") worked with the participating TAs. The TA mentor had previously taken the same TA training program as the TAs and subsequently practiced teaching and learning in education leadership positions in the College of Engineering and the University. They had also designed and taught two summer engineering courses as sole instructor.

The program lead is the professional staff member who leads the College's peer education initiatives, drawing on 20+ years as a professor in STEM, scholarship and experience in evidence-supported pedagogy and learning outcomes assessment. They co-designed the initiative with the TA mentor, provided guidance throughout, and collaboratively participated in the implementation and assessment.

Program structure and summary of the activity design process

The program lead and the mentor met briefly with the participating course instructors and their TA(s) to explain the goals and objectives early in the semester. The mentor subsequently met with the course TA(s) and shared the backward design process [7]. In summary, the design sequence is: determining the learning outcome, designing an assessment to measure if students accomplished the outcome, and designing an activity to help students accomplish the outcome. As another step, this program included designing retrospective post-assessment questions to help students self-identify if they accomplished the outcome.

After initial meetings, program participants had regular weekly or biweekly meetings. The frequency of these meetings mainly depended on the TAs' availability and the instructors' preferences. On average, for a single activity, each instructor spent 20 to 50 minutes meeting with their TA(s), and TA(s) spent 100 to 160 minutes meeting with the instructor and the mentor. The mentor spent 150 to 200 minutes meeting with the TAs and performing additional administrative duties, including weekly check-ins with the program lead for feedback and troubleshooting.

Results and Discussion

Summary of designed activities

Throughout the program, TAs and instructors designed and implemented a total of 13 activities in 4 courses. The number of activities designed in each course varied between one and seven. Table 1 summarizes techniques and questions the TAs used while designing these activities.

Table 1 Characterization of interactive problems and post-assessment reflections developed by TAs and the mentor.

Interactive learning techniques: solving multiple problems simultaneously:	**Interactive learning techniques: solving a single problem using a single method:**	**Interactive learning techniques: solving a single problem using different methods:**	**Retrospective post-assessment questions: perceptions of learning and confidence:**	**Retrospective post-assessment questions: value of collaboration:**
Partners solve different questions relating to the same topic individually, then explain their solutions to each other.	Partners instruct each other to solve a single problem.	Students in a small group find few viable solutions to an open-ended problem.	Reread the learning outcome. Do you think you accomplished this outcome after completing this activity?	Did you find collaborating with classmates helpful?
Partners solve different questions relating to the same topic individually, then explain each other's solutions to each other.	Partners take turns while solving a single problem.	Students in a small group solve the same question using different methods, identify the advantages and disadvantages of their method, and describe them to their group.	Did you find that the learning activity improved your confidence in the learning outcome?	Did you find collaborating with classmates fun?
Students in the classroom perform a jigsaw activity. [8]	Students in the classroom physically demonstrate a real-life process involving multiple components.	Students in a small group solve the same question using different methods, then explain their methods to each other.	How do you think this learning activity helped or hindered in achieving the learning outcome?	Did you find the activity enjoyable ?
Partners find analogies to describe different concepts to each other and share their partners' analogies with the classroom.	Students in the classroom experiment with a real-life object and identify governing equations.		How did this activity affect your attitude towards tackling these problems?	

Summary of student participation and participant feedback

In general, students were willing to participate in the interactive activities and answer the retrospective post-assessment questions. Specifically, the percentage of students who answered the post-assessment questions varied from 34% to 92%, with an average of 62%. The number of students who answered the questions decreased as the semester progressed, with the average participation in the first and last activities of all courses being 72% and 57%, respectively. We used students' answers to these questions to identify the changes in their perceptions of learning, confidence, and perceived value of collaboration in lectures. Table 2 illustrates a (limited but representative) data analysis from one activity in each course. In addition to these quantitative results, most students provided insightful narrative feedback to these activities. In all cases, their feedback was strongly positive. Students broadly indicated that these activities improved their understanding of the material and increased their confidence in the topic or process. In addition, they mentioned that working with peers was valuable and even, mostly, fun.

Table 2: Results of a representative data analysis from one activity in each of the participating courses. ' - ' indicates that a particular question was not in the corresponding retrospective post-assessment survey.

Response category	**Students' answers to "Are you more confident in your understanding?"**					**Students' answers to "Was collaboration helpful for your understanding?"**				
Course identifier	**1**	**2**	**3**	**4**	**Average**	**1**	**2**	**3**	**4**	**Average**
Yes [%]	53	-	79	70	67.11	72	84	95	71	80.5
Maybe [%]	21	-	11	21	17.61	19	6	0	17	10.5
No [%]	26	-	11	9	15.28	9	10	5	12	9

At the end of the semester, four of the six participating TAs completed anonymous surveys, including Likert-scale and narrative-style questions regarding their experiences with this program. In general, two of the four TAs had a very positive experience, learned more about student-centered teaching, felt adequately supported, and strongly agreed that they gained confidence. Three of the four TAs had experiences that ranged from slightly positive to very positive. One TA was not and is not interested in teaching and did not gain much from participation. (Likely this was not a good candidate for participation in a teaching-focused project, but perhaps the value was helping them decide against teaching in their future.) Overall, the TAs' narrative responses suggest that they valued the mentor's support and

resources. They also suggested that it was more challenging to design student-centered learning than they had expected and would choose to include student-centered learning in other teaching contexts in the future.

Three of the four participating instructors completed anonymous surveys (similar to the TAs' survey in style and theme) at the end of the semester. In general, this group of instructors valued the initiative, and at least two of the four voiced their interest in participating again in the next iteration. In addition, two of the three respondents strongly felt that the time they spent was valuable, they got the support they needed from the program facilitators, and they would encourage colleagues to be involved. They also said that the TAs successfully designed and implemented the activities.

We observed that the TAs became more confident, the quality of their designed activities improved, and they needed less help with designing activities as time went on. We also noticed that the TAs learned to be more mindful of their actions in the classroom and the students' reactions to them. Moreover, in addition to designing student-centered learning, the TAs learned how to encourage students to participate in the classroom, be transparent about their thought processes while solving problems to demonstrate expert thinking, and react to students' incorrect answers or results while emphasizing that people learn by making mistakes. Finally, our subjective impression was that, throughout the semester, the outcomes were the strongest where the instructors were the most positive and discussed, and mainly entrusted the activities to the TAs. Not surprisingly, these TAs articulated having the best experience (both in surveys and conversation with the mentor).

Conclusions

We consider this a successful pilot. First, it benefited TAs who want experience and confidence in their teaching. Second, it infused lectures with more positive, collaborative activities that both participating students and instructors acknowledged as valuable and helpful for learning and confidence building. Finally, it introduced some instructors to more student-centered strategies than they have seen previously, with a model that takes most of the time for development out of the hands of instructors.

Literature Cited

[1] M. T. H. Chi, "Active-constructive-interactive: a conceptual framework for differentiating learning activities," *Top Cogn Sci*, vol. 1, no. 1, pp. 73–105, Jan. 2009, doi: 10.1111/j.1756-8765.2008.01005.x.

[2] M. Menekse, G. S. Stump, S. Krause, and M. T. H. Chi, "Differentiated Overt Learning Activities for Effective Instruction in Engineering Classrooms," *Journal of Engineering Education*, vol. 102, no. 3, pp. 346–374, 2013, doi: 10.1002/jee.20021.

[3] K. D. Tanner, "Promoting Student Metacognition," *CBE Life Sci Educ*, vol. 11, no. 2, pp. 113–120, 2012, doi: 10.1187/cbe.12-03-0033.

[4] A. Siegesmund, "Increasing Student Metacognition and Learning through Classroom-Based Learning Communities and Self-Assessment," *J Microbiol Biol Educ*, vol. 17, no. 2, pp. 204–214, May 2016, doi: 10.1128/jmbe.v17i2.954.

[5] J. Gyurko, P. MacCormack, M. M. Bless, and J. Jodl, "Why Colleges and Universities Need to Invest in Quality Teaching More Than Ever." Nov. 2016. [Online]. Available: https://acue.org/wp-content/uploads/2018/07/ACUE-White-Paper1.pdf

[6] P. B. Stark and R. Freishtat, "An evaluation of course evaluations," *ScienceOpen Research*, vol. 0, no. 0, pp. 1–7, Sep. 2014, doi: 10.14293/S2199-1006.1.SOR-EDU.AOFRQA.v1.

[7] G. Wiggins and J. McTighe, "What is Backward Design?," in *Understanding by Design*, Association for Supervision and Curriculum Development, 1998. Accessed: Oct. 22, 2021. [Online]. Available: https://web.archive.org/web/20160721163755/http://www.fitnyc.edu/files/pdfs/Backward_design.pdf

[8] "The Jigsaw Classroom." https://www.jigsaw.org/ (accessed Feb. 17, 2022).