Catalyzing Active Learning: Implementing Active Learning Across an Engineering and Science College

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Abstract

A cohort model was implemented in a college of engineering and science at the University of Minnesota Duluth (UMD) after initiating a strategic development plan to create cultural and pedagogical change in undergraduate classrooms to engaged and active learning environments. The initial cohort consisted of faculty from Chemical Engineering, Chemistry, Computer Science, Civil Engineering, Mathematics, Mechanical Engineering, the Dean of the College of Science and Engineering (SCSE) and a facilitator from the University of Minnesota's Center for Educational Innovation (CEI). The cohort meetings began in January with focus on theory of learning and best practice of teaching using active learning strategies. The foundational readings and facilitated discussion were developed around the book *How Learning Works*, by Ambrose et al. Practical integration of current research and practice of active learning into undergraduate classrooms was followed by continued work in the summer months to redesign a course for fall semester incorporating active learning strategies. During the fall implementation, the cohort continued to meet to talk about experiences in their courses and to plan workshops and dissemination of outcomes/uses of active learning to all faculty in SCSE. At the end of fall semester, the cohort model solicitation was sent to the entire faculty in SCSE, with new cohorts starting in spring semester. The second year of the model is currently in progress with 38 participants from the faculty selected to populate six small multidisciplinary cohorts. The initial faculty cohort team comprises five of the six facilitators of the new cohorts. Moreover, all seven members of the initial faculty cohort continue to meet. This community of practice is leading the development of additional workshops, implementation of an assessment/evaluation framework to document the effect of active learning as this continues and expands through SCSE, writing grant proposals to enable further dissemination of the multidisciplinary cohort model approach across a college of engineering and science, and supporting each other's individual research endeavors.

Introduction

This paper describes Work in Progress (WIP) efforts to increase active learning in a college of engineering and science. Motivation for this project came from a desire to increase retention of students in science, technology, engineering, and mathematics (STEM) fields, student performance, and retention of student knowledge. Retention of underrepresented minorities and women is of particular interest. The University of Minnesota Duluth (UMD) is a regional comprehensive university with an undergraduate enrollment of approximately 9,000 students. The Swenson College of Science and Engineering (SCSE) includes four engineering departments (chemical, civil, electrical, and mechanical & industrial) and six science departments (biology, chemistry & biochemistry, computer science, earth & environmental sciences, mathematics & statistics, and physics). The SCSE enrollment is 3,098 undergraduates and current 5-year graduation rate is 68%. The SCSE tenured and tenure-track faculty typically teach two courses per semester with additional laboratory instruction requirements. As a regional comprehensive university, UMD's experiences in this process are relevant to numerous other universities throughout the county.

The transition to active learning is being driven both from the office of the Dean of SCSE and grass-roots faculty efforts. Hence, the growth of adoption of active learning is centrally supported both by administration and collegial peer groups. This approach socializes the adoption of active learning in small groups through facilitation of faculty learning communities (FLCs). The current small groups of seven to ten members will grow in future years to include more faculty each year. Presently, approximately 20% of the 180+ faculty of SCSE are engaged in implementing some form of active learning in their classrooms. The goal is to use active learning methods in all classes by 2025. This paper summarizes the known benefits of active learning methods and presents SCSE's experience with the initial faculty cohort as a way to propagate change towards increased adoption of proven strategies. Assessment techniques designed to quantify effectiveness of increasing active learning throughout the college are described. Finally, methods of assessing faculty attitudes towards active learning are presented.

Background

Felder and Brent define active learning as "anything course-related that all students in a class are called upon to do other than simply watching, listening, and taking notes." [1] Research has demonstrated that active learning improves student retention. [2,3] Therefore, educating more SCSE faculty in active learning techniques and providing them a support structure should help with a campus goal of retaining and supporting a diverse student population. Additionally, improving student outcomes through increased faculty commitment to active learning would help ensure that students are able to make timely, continuous and satisfactory progress toward degree completion.

Active learning mitigates several structural barriers to inclusion of underrepresented minority groups such as women in science and engineering. [3] Moreover, two of the authors of this paper have already seen anecdotal evidence in the form of direct student feedback from women in their active learning classrooms showing a higher interest in the subject matter. One student stated, "I feel like I'm learning the material better and I'm finding chemistry way more interesting than I ever thought I would." Thus, this project aims to support academic success at the course level by applying proven active learning techniques to improve student outcomes, as well as at the department and college level by increasing the number of faculty committed to active learning and helping set a department and college expectation for active learning.

The major motivation for moving SCSE to an active learning paradigm is that research has demonstrated active learning is more effective than passive lecture-based learning. Felder et al. describe lecturing as an effective method of accomplishing short-term retention of facts in large groups. [2] As STEM fields strive for long-term understanding, passive lecturing is not an effective method of accomplishing SCSE's goals. Freeman et al. report higher performance on exams and decreased failure rate in STEM courses where active learning techniques were employed compared to similar courses taught passively. [4] Prince illustrates that active learning increased student retention of course material. [5]

SCSE is using cross-disciplinary cohorts, comprised of small groups of 7 to 10 members from different departments, in the form of faculty learning communities (FLCs) to expand the population of faculty using active learning methods. The cross-disciplinary FLC engages in an active, collaborative curriculum focused on enhancing teaching and learning to provide development and community building. FLC members participate in discussions facilitated by an expert (here expert is defined as someone with more knowledge than the FLC group at large members), who is generally following a series of pre-defined topics and who may assign readings or other tasks to the FLC members as pre-work to the group discussions.[6,7]

Increasing faculty adoption of active learning

To transform SCSE's culture and increase the adoption of active learning strategies across the disciplines, FLCs are underway. As presently organized, this approach to promoting faculty adoption follows research that shows successful change management strategies emphasize creativity, flexibility and collaboration. [6,7] There is institutional support in the form of small grants from the Dean's office for travel and technology needs, and through instructional research and development resources offered by the University of Minnesota's Center for Educational Innovation (CEI). This approach is flexible and it appeals to multiple learning styles in that FLCs may be formed around new teaching topics as needed and can dissolve or shift as expertise is gained by the FLC members.

On a larger scale, routines will be implemented into the daily structure through the dedication of time for faculty, administration, and staff to focus on discussions surrounding teaching. This could occur together within a single department or collectively as a college. Some examples include:

1. Holding two workshops on teaching pedagogy per semester to be led by staff from the CEI and other national leaders in innovative teaching pedagogies.

2. Holding faculty-led symposia each semester on case studies and examples of innovative teaching occurring throughout SCSE with special emphasis on those leading the implementation. The symposia and workshops will provide information on best practices, results of innovative strategies and research projects within the program, and provide a forum for teachers to socialize about teaching in multidisciplinary settings, thus creating a teaching and learning community that spans the disciplines.

3. Dedicating time in departmental faculty meetings to first personalize the vision of this proposal for their department and then to share teaching pedagogies tried in classes as well as techniques for implementing classroom changes, thus creating learning organizations within each department.

The three routines described are focused on continuous learning and improvement. They develop new ideas that lead to changes. Furthermore, they make continual changes to the overall structure, seek grassroots innovation, and involve people with different views, thus increasing buy-in among the major stakeholders. The passing of expertise in integrating active learning into STEM curriculum is envisioned as a continuous cycle allowing all faculty to rotate into and away from cohorts, classroom implementation, or workshops and seminars following their specific development needs as shown in Figure 1.

In SCSE, a small grant from the CEI enabled the formation of the first FLC which was facilitated by a professional from the Center for Educational Innovation. This group, known as Cohort 1, was identified and invited into the cohort by the Dean of SCSE based on prior expressed interest in active learning or current use of active learning in their courses. The FLCs plan is to break into smaller sub-groups to tackle items as varied as coordination of college-wide assessment of student and faculty attitudes to the creation of a “boot-camp” for incoming majors to level set student expectations for active learning versus more traditional lecture only formats. The authors envision that with time, multiple FLCs will align around other common themes such as developing a set of pre-knowledge exams to measure student knowledge retention between courses. Additionally, the members of Cohort 1 who experienced the full year long sequence facilitated by CEI are the leader/facilitators for the second wave of FLC discussions.

For the second wave of cohorts, all faculty within SCSE that wished to join were able to do so. This resulted in 6 total cohorts, made up of 5-7 people per cohort, totaling 38 participants. Faculty interest in the cohorts was much higher than anticipated, which was likely motivated by several factors. UMD is a regional comprehensive that has a good balance between research and teaching, where teaching is valued at a level similar to research. The Dean is relatively new and has been talking to the college since his arrival about the need to transition to active learning. The faculty in the initial cohort spoke frequently to their departments about their experiences in the cohort, thus the idea of these communities was brought to the faculty both from the top administration as well as from assistant professors and instructors within the Departments. Faculty were offered the chance to apply for funding to help with teaching or support for rewriting their curriculum, thus acknowledging and valuing the time required for changing and innovating courses.

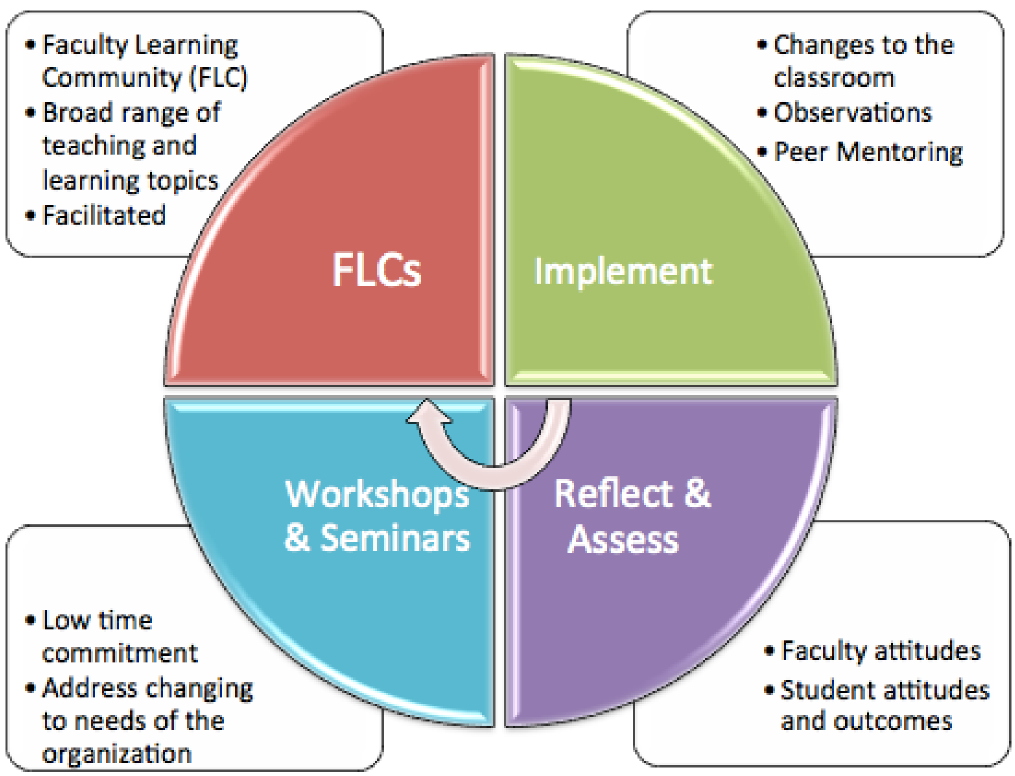

Figure 1: A continuous improvement cycle to promote a learning organization wherein SCSE faculty may choose to be involved in any one quadrant or all four spaces of activity depending on their individual professional development goals and time availability.

Finally, a mentored teaching program is planned that will provide professional development support for incoming new faculty as well as middle- to late-adopters of active learning. The faculty mentors will be those who have participated in a community of learning, identified on campus as an Innovative Teaching Cohort, and who have learned best practices in teaching pedagogy. These faculty mentors will be trained for peer observations in order to provide effective feedback to mentees. The mentored teaching opportunities will fit well for new faculty members during their first or second semester coincident with the semester they receive a course release. For middle- and late-adopters a mentored teaching experience would ideally occur in conjunction with receiving a grant for a course release to modify curriculum. The experience will be focused around observing the mentor teach and interact with the students, learning the structure of the class, and getting the opportunity to lead an activity or class discussion.

Work to Date:

The first FLC began a year ago when SCSE created the first multidisciplinary Innovative Teaching Cohort (Cohort 1) of six teaching innovators to learn and implement active learning into a class of their choosing. This was the first step in innovating teaching across SCSE, with the long-term goal of incorporating these techniques across SCSE within ten years. The faculty met regularly (biweekly or monthly) with a facilitator from CEI such that over the course of a year, they learned and discussed evidence-based teaching methods, redesigned their respective courses, and implemented the course redesigns during the Fall and Spring semesters. The cohort has also organized several college-wide workshops on active learning and is collecting baseline data on student attitudes and student learning for the college. These “teaching innovators” have been trained to be peer observers for other instructors to assist faculty in moving to active learning.

The breadth of courses affected by the initial cohort crossed disciplines and levels of undergraduate programming. Within the initial cohort faculty, courses that were redesigned included freshman level General Chemistry II (flipped classroom design), freshman level Calculus I (engaged problem solving in a 150 student stadium seating large lecture section), junior level Fluid Mechanics (flipped classroom design), junior level Soil Mechanics and graduate level Soil Shear Strength class (implemented Excellence in Civil Engineering Education (ExCEEd) model), junior/senior level Human Centered Computing (project based learning), and Introduction to Chemical Engineering (project based learning).

Data on student impacts is forthcoming. However, preliminary data on the effect of implementation of active learning strategies in cohort classrooms is available and shows results consistent with research literature. In a junior-level civil engineering class, the D/fail/withdraw (DFW) rate dropped from 8% in three semesters taught using passive learning methods to 3% in two semesters taught using active learning methods. Evaluations in the same course increased in all 14 of UMD’s student evaluation questions. In addition, students from a junior level Fluid Mechanics course in Mechanical Engineering that adopted a flipped format were surveyed in relation to three other mechanical engineering courses taught in a primarily passive mode and showed statistically significant improvements in all aspects surveyed [8].

In the freshman-level General Chemistry II class, the same instructor taught both a traditional lecture section and a flipped class for a systematic comparison. Students took the same exams and covered identical content but in differing formats. While the two sections differed in size, with 111 students in the lecture section and 49 students in the flipped section, they did not differ in incoming GPA, ACT score or scores on a pre-class test of Chemistry knowledge, nor did they differ on any of the available demographic variables (sex, age, year in school, major, and ethnicity). The results confirm that the flipped format enhances student learning. After controlling for students' incoming GPA, prior chemistry knowledge, status as a major/non-major and sex, students in the flipped section performed 3.88% higher in their average exam score ($p = .012$) and 5.45% higher in their end of semester grade ($p < .001$). In addition, the DFW rate was significantly lower in the flipped section of the course (16% vs 32%; $\chi^2 = 3.999$, $p = 0.46$).

Faculty development and efforts to increase interest in active learning has already born fruit. An example is adding 38 faculty members to the second Active Learning Cohort. A two-day SCSE Teaching and Learning Workshop on backward course and lesson design based on learning objectives and methods of increasing active learning was attended by 24 faculty from seven departments. SCSE will offer two two-hour workshops focused on active learning each semester lead by CEI experts. The first offering attracted faculty from every department in the SCSE. The first workshop is titled Active Learning 101 and was attended by 34 faculty. Designing Your Course for Active Learning, the second workshop, was attended by 24 faculty.

A second wave of innovative teaching cohorts is underway at two levels. Level one facilitation is disseminating proven strategies in active learning to inexperienced faculty as well as experienced faculty members who have only taught using a traditional, passive lecture, teaching format. Level two faculty members are also being engaged in this second wave of cohorts but generally have some experience in active learning as well as a desire to research new techniques.

We predict that this combination of FLCs and administrative actions will support pilot studies and foster a research-to-practice continuous improvement cycle of innovative instruction. In this way, as new courses are developed or existing courses transition to a new format (i.e., in-person to hybrid or online teaching), the faculty doing the work should encounter a supportive environment that fosters the communication and sharing of resources to reduce the barriers to change. This approach is also hypothesized to be a beneficial onboarding tool for newly hired faculty.

Lessons Learned

The first Innovative Teaching Cohort began in January of 2015 and has been meeting weekly ever since. The members of this multidisciplinary cohort now make up a college committee on active learning. Several lessons were learned over the course of the last year and have now been implemented into the second year of cohorts and include:

- Reading the book *How Learning Works* by Ambrose et al. [9] A text helped to facilitate the weekly discussions around different aspects of learning. The discussions prompted natural brainstorming among the group on different activities to use in class based on the component of learning being discussed that week.

- Having an expert facilitator, in our case from CEI, was a necessary resource. The group members were new to active learning and the supporting literature. The facilitator was extremely helpful in addressing concerns using literature-based evidence and also in helping to generate solution ideas to many of the common problems when thinking about implementing active learning, such as: ability to cover necessary content, how to implement in large lectures, getting around stadium seating, to name a few.

The cohort model turned out to be an excellent mechanism for faculty from different disciplines to have the chance to talk about curriculum, especially between departments that provide courses for majors from other departments (i.e., computer science and engineering). As a result of improved communication between departments, a new Introduction to Computer Science course is being developed for engineering students' computer science requirement. In addition, examples of engineering problems involving multivariable calculus and statistics are now being used to motivate math concepts, providing students with contextual learning opportunities that illustrate the necessity of acquisition of the content knowledge for later coursework.

Future Plans

The effectiveness of this program will be assessed in several ways. First, data on student retention and minority populations are currently recorded and will continue to be recorded at the department, college, and university level. As more SCSE faculty are trained and conduct their classes in an active fashion, data from the 2013-2014 academic year and prior will be compared to future academic years.

Student outcomes will be measured at both the course and program level. At the course level, outcomes will be measured through student performance on equivalent homework and exam problems and through student attitude surveys. Consultants from CEI will work with the cohort to develop attitude surveys and select appropriate standardized assessments. In fall 2016, pre-tests assessing pre-requisite course material retention will be included in capstone courses across SCSE departments. Content of the pre-tests will be developed at the program level. Since active learning promotes the retention and successful application of prior knowledge, both quantitative data from the pre-tests and qualitative data from exit interviews are expected to show statistically significant positive change as a result of this initiative. [9]

Student outcomes at the program level will be assessed using student attitude surveys and quizzes in capstone courses on pre-requisite material. The survey is intended to measure the first three aspects of scientific literacy (understanding of the nature and processes of science, affect and attitudes towards science, and beliefs about the connections between science and everyday life), as well as student attitudes toward and beliefs about different sorts of learning activities. It draws on existing scientific literacy surveys, including the University of Minnesota College of Biological Sciences Core Survey [10]; the Attitudes and Conceptions in Science survey [11]; the Test of Scientific Literacy Skills [12]; the student attitude survey developed by Hillyard et al. [13]; and the CLASS survey [14]. These assessments will begin in fall 2016 with the current SCSE cohort to develop baseline data for future comparison. It is hypothesized that trends of active learning increasing retention of underrepresented minorities will be replicated at UMD, therefore, SCSE hopes to create opportunities for students to interact with people from different ethnic and socioeconomic backgrounds through this project.

Since this project is predicated on improving student outcomes by moving to more active learning in required courses, faculty buy-in is critical. As noted by Fairweather and Paulson, the greatest gains in improving STEM education will come from finding ways to engage "the majority of faculty, which as a collective make the least use of active and collaborative instructional methods widely found to increase student learning."[15] At present, all data on faculty use of active learning is self-reported.

Faculty receptiveness to active learning practices will be measured by tracking registration and attendance at regularly scheduled active learning workshops. Additionally, tracking interest and participation in the Faculty Learning Communities will provide data on the number of faculty genuinely willing to dedicate time to improving their teaching.

More directly, faculty perception of active learning throughout SCSE will be assessed through attitude surveys, developed in conjunction with CEI consultants, beginning in fall 2016. This survey was adapted with permission from the Attitudes toward Active Learning questionnaire described in Pundak et al.[14] The original questionnaire and this survey were designed to probe general faculty satisfaction with teaching as well as several known sources of faculty concern about active learning. These include content coverage, the difficulty of implementing active learning techniques in large classes, lack of knowledge and skills regarding active learning, opposition among colleagues, and student resistance. Assessments will continue as the college increases the percentage of its classes taught using active techniques. Attitude surveys will be supplemented with quantitative data recording the percentage of faculty using active learning techniques and percentage of SCSE active learning courses.

Conclusions

A multidisciplinary faculty cohort model was developed following a hybrid change strategy approach in order to transition the teaching culture in a college of science and engineering to active learning through a research and best-practice based approach. The first faculty cohort spent one semester developing breadth and depth of understanding of learning theory and best practice as related to active learning. This was followed by a summer of course redesign. The culmination of the first year cohort was implementation during fall semester courses across SCSE. In addition, the cohort developed and offered workshops for all faculty in the college, collected baseline data on undergraduates across SCSE, disseminated findings and ongoing strategic plans, and wrote proposals to continue the transition of SCSE to active learning. The first year and first cohort was comprised of 6 faculty members, a CEI facilitator, and the Dean of SCSE. The success and efforts of the initial group of early adopters of active learning has resulted in greater than 500% increase in the number of faculty in the SCSE interested in intentional focus on active learning strategies and implementation in their classrooms. One year later, the cohort of 7 has grown to 45 faculty members for the second year.

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