2018 ASEE Annual Conference & Exposition
June 24–27, 2018 Salt Palace Convention Center Salt Lake City, UT

Paper ID #21816

Transforming an Institution by Engineering Learning

Dr. Sam Spiegel, Colorado School of Mines

Dr. Spiegel is the Director of the Trefny Innovative Instruction Center at the Colorado School of Mines. He previously served as Chair of the Disciplinary Literacy in Science Team at the Institute for Learning (IFL) and Associate Director of Outreach and Development for the Swanson School of Engineering's Engineering Education Research Center at the University of Pittsburgh. Prior to joining the University of Pittsburgh, he was a science educator at Biological Sciences Curriculum Study (BSCS). Dr. Spiegel also served as Director of Research & Development for a multimedia development company and as founding Director of the Center for Integrating Research & Learning (CIRL) at the National High Magnetic Field Laboratory, Florida State University. Under Dr. Spiegel's leadership, the CIRL matured into a thriving Center recognized as one of the leading National Science Foundation Laboratories for activities to promote science, mathematics, and technology (STEM) education. While at Florida State University, Dr. Spiegel also directed an award winning teacher enhancement program for middle grades science teachers, entitled Science For Early Adolescence Teachers (Science FEAT).

His extensive background in science education includes experiences as both a middle school and high school science teacher, teaching science at elementary through graduate level, developing formative assessment instruments, teaching undergraduate and graduate courses in science and science education, working with high-risk youth in alternative education centers, working in science museums, designing and facilitating online courses, multimedia curriculum development, and leading and researching professional learning for educators. The Association for the Education of Teachers of Science (AETS) honored Dr. Spiegel for his efforts in teacher education with the Innovation in Teaching Science Teachers award (1997).

Dr. Spiegel's current efforts focus on educational reform and in the innovation of teaching and learning resources and practices.

Dr. Megan Sanders, Colorado School of Mines

Megan Sanders is the Senior Assessment Associate at the Trefny Innovative Instruction Center at the Colorado School of Mines. Before joining Mines, Megan worked at the Eberly Center for Teaching Excellence and Instructional Innovation at Carnegie Mellon University, where her role focused on supporting instructors in conducting research about student outcomes in their courses. Megan's disciplinary background is in educational psychology. She earned her PhD from the Ohio State University, and her research focused on the idea of relevance in higher education—how we define it, how students perceive it, and how to measure it—an interest that continues to inform her work.

Dr. Jennifer Zoltners Sherer, University of Pittsburgh

Jennifer Zoltners Sherer is a Research Associate at the University of Pittsburgh's Learning Research & Development Center. Her work focuses on developmental evaluation, initiation and development of networked improvement communities (NIC), and improving STEM teaching and learning. Her research interests include distributed leadership, organizational change, and improving teaching and learning through tool design and implementation, professional development, reform initiatives, and curriculum. Prior to receiving her Ph.D. in Learning Sciences from Northwestern University, she was a teacher in Oregon.

Transforming an Institution by Engineering Learning

This paper explores the transformations underway to advance teaching and learning at a public institution of higher education. The transformations are multi-level, targeting both individual impact for faculty through to systemic changes at the institutional level. The transformations are catalyzed and supported by a Teaching & Learning Center (the Center) focused on faculty development, curricula, and systemic change through facilitated professional development, a focus on learning, and the implementation of new structures, routines, and tools. The transformations are institutionally grounded and are the result of combined efforts (e.g., President's office, Provost, Deans, Faculty, Center), with the Center as a catalyst. The Center was created in response to a multi-year strategic initiation process. Shortly after formation of the Center, there were complementary shifts in senior administration (new President and Provost). In this paper we report the framework used to guide the transformations to advance teaching and learning, share ways we organized to facilitate the changes, and provide case examples to illustrate some of the impact of the transformations.

University leadership charged the Center with institutional transformation. While the Center has been the primary lead and support for the transformation efforts, it is worth noting that there were other factors and supports across campus that accelerated the institutional changes. To understand our approach to change, we begin with a brief overview of organizational communication, institutions and systemic change.

Institutions are more than the sum of their people, place, environment and resources. They are dynamic establishments with a common purpose and communication patterns that congeal the organization [1]. Institutions are formed by the interactions of the people, in the context of the common purpose, and organized within the social, capital, political, and physical resources available to the institution [2], [3], [4]. The institution is formed and reformed both internally (by those who function within the institution such as students, faculty, staff, administration, alumni) and externally (e.g., alumni, other institutions, parents, perspective students, media, politicians) [5]. While both internal and external interactions[1] impact aspects of the institution, for this study we focus[2] on the internal interactions as we seek to understand and transform the institution and also describe the impact of our work.

While one can debate the primary goal and purpose of institutions of higher education (e.g., helping prepare future workforce, creating a fairer and more just society, self-fulfillment, creating prepared minds, developing future academics), most will agree a core goal of higher education is or at least should be *education* or *learning* [7], [8]. For the purposes of this paper, we work from the perspective that learning is at the core of institutions of higher education.

As we began our efforts to systemically advance innovations in teaching across campus, we (teaching and learning center staff) learned from preliminary interactions that faculty were struggling to make sense of what we meant by various educational terms. Additionally, most faculty had no pedagogical training and little to no understanding of cognition and how to

---

[1] In an earlier paper the theoretical perspectives that inform our work is described in greater detail [6].
[2] We did take into account external factors in the design and planning of the interventions, but that was a second level consideration and will not be addressed in this paper.

optimally design for effective learning. In an effort to make the intended work more accessible to faculty, we developed "Engineering Learning" as a framework to help faculty begin to think differently about teaching and learning [9].

Engineering Learning Framework

Engineering Learning is a framework that guides faculty through an intentional design process. One purpose of the framework is to shift faculty from focusing on the delivery of content (covering content), to the role of designer and facilitator of learning (learning engineer) [8]. The Engineering Learning design process is based on backwards design [10] and connects to research-based teaching approaches by creating the space (time or pause) and probes to have faculty focus on thoughtful learning outcomes, aligning assessment and tasks to those learning outcomes, considering how to utilize talk and task designs to enhance student engagement and learning, and focusing on data-driven learning opportunities [11], [12], [13], [14], [15]. To engage in Engineering Learning changes the conversation from one of "covering content" to one focused on student learning. Engineering Learning requires significant shifts in the ways faculty approach teaching and learning in higher education. Our intent in using this framework is to realign instruction with 1) current research-based approaches to teaching and learning, 2) changing student needs, 3) student passions and interests, and 4) the practices and understandings desired by industry and needed for the world of tomorrow [9]. Figure 1 illustrates the Engineering Learning framework.

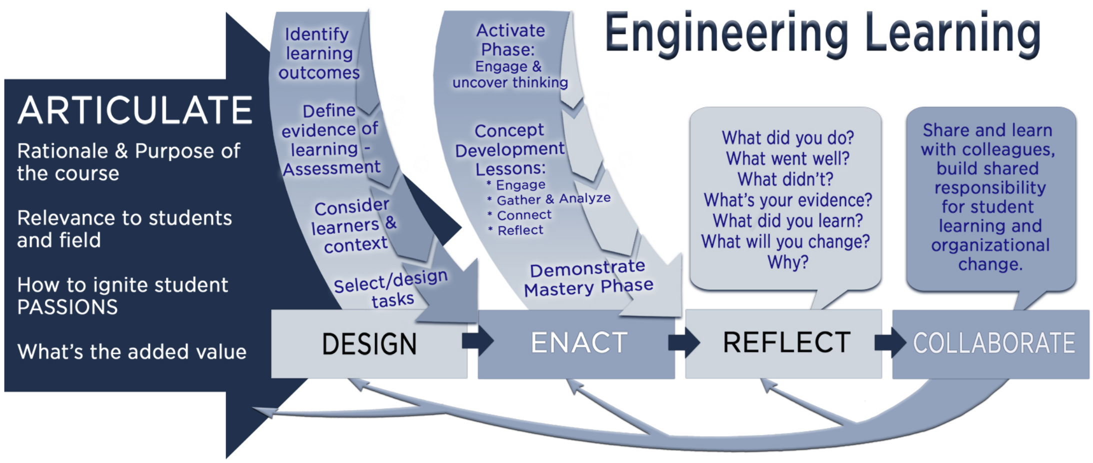


Figure 1. Engineering Learning framework [9]

To implement Engineering Learning at the Colorado School of Mines (Mines), we have developed and enacted several specific practices at the institutional, college, departmental, and faculty levels[3]. At the institutional level, with support from university leadership, we have begun to shift the general perspective of faculty to that of designers of learning opportunities by creating funding models that provide time for faculty to design or revise existing courses. At the college and department level, we have facilitated workshops to help campus leaders identify

[3] These are not listed in order of importance but rather in the order in which we focused more significant efforts. We focus on working with faculty with the intent of ultimately reaching students. There are numerous simultaneous efforts targeting each of the stakeholder levels.

ways to support their faculty as the faculty begin redesigning courses and changing their teaching practices. At the faculty level, we have engaged 20% of our faculty in our intensive, month-long professional learning experience focused on Engineering Learning and requiring a significant course redesign. These examples illustrate some of the specific practices we are using to introduce Engineering Learning across the institution. Below we outline the faculty level professional development efforts to introduce and systematize Engineering Learning as a framework to guide teaching and learning on campus.

Professional Development to Transform the Institution

To truly change one's practices, faculty need to change their understandings and beliefs about teaching and student learning. These difficult changes are enabled by thinking about the problem or situation in a new way. Creating this dissonance that leads to new understanding and beliefs can happen through self-directed or facilitated learning. As faculty begin to change their practices, they need a safe and productive environment where they feel supported and encouraged to make the changes. Creating this safe and encouraging environment requires systemic shifts. These shifts facilitated by the Center are many in number, often connected, and complex in nature. They include:

- developing a common vision across campus that teaching and learning are important
- gaining and communicating support of Administration (i.e., Department Heads, Deans, Provost, President, Faculty Senate)
- changing policies to be consistent with the changes
- shifting organizational practices (e.g., scheduling of classrooms to match teaching design, rather than classroom spaces determined only by number of students)
- supporting time to redesign courses
- adding institutional resources to collect and analyze data to inform practices.

Students also need to become educated about the new practices, as change creates uncertainty, discomfort, and can lead to "grumpy campers" [14]. In this paper we focus on the professional development efforts of the Center with the faculty.

Center staff works with faculty in a variety of ways and at varying levels of intensity or interaction. The ways in which we work with faculty include leading and supporting through:

- consultations and coaching,
- responding to questions related to teaching and learning,
- addressing classroom infrastructure needs,
- offering learning opportunities (e.g., seminars, workshops, self-paced online modules, and courses both facilitated online and face-to-face), and
- gathering, analyzing and sharing evidence (data) about teaching and learning on campus.

Through all of these ways of working with faculty we use the Engineering Learning framework to guide and frame the work.

Our most intensive and impactful approach is the Summer Intensive Course Revision program. This program is funded for three years (three cohorts). We have completed two years of the professional development aspect of the program.

The purpose of this initiative is to provide focused time for a cohort of faculty to learn new pedagogy and course design theory, work both collaboratively and independently as they focus on enhancing their teaching, and significantly revise a course that will be taught by the faculty member during the subsequent school year. The overall intent of the program is to significantly and systemically enhance teaching and learning at Mines.

The university provides each faculty member one month of support in July/August to participate in this intensive learning and working session. The summer session includes classes, readings, and time to work alongside pedagogy and curriculum experts as faculty design or revise a targeted course. There are also intentional breaks woven in to the schedule to allow faculty to pause and apply the new learning to their own teaching plans. The overall goals and focus of the learning for the program are:

- Design or significantly revise a course of study utilizing sound pedagogical practices. The design and enactment will be based on the Engineering Learning framework. This includes, but is not limited to:
    - clear articulation of learning outcomes,
    - designing/selecting rich assessments that are aligned to the learning outcomes (includes the use of formative and summative assessments,
    - strong task design,
    - support for diverse learners, and;
    - refining course instructional sequence and design to increase coherence in the learning progression and content.
- Create a student-centered syllabus and course map for the revised course.
- Design rigorous learning experiences for the targeted course that actively engage students to achieve or exceed the course learning outcomes.
- Develop new approaches and repertoire of research-based practices to more effectively implement the course design.
- Develop reflective practitioner skills to enact continuous improvement through the regular collection and analysis of data.
- Connect with colleagues to form a support learning community and cohort; build strong collaborative relationships to support continuous learning and instructional improvement beyond the workshop.

We first engage faculty as learners, immersing them in a learning experience around a STEM topic that we can reasonably predict faculty will begin with common misconceptions. This positions them as learners and provides a reference point across the program as they seek to design similar experiences for their students. We then teach faculty about Engineering Learning and they apply the framework to the course they want to redesign. Engineering Learning grounds their learning in the practice [16]. The Center also investigates the impact in all the courses.

Across the five-week program, faculty work to significantly revise a course. The course revisions may include revised learning goals, activities, teaching methods and course delivery, and/or assessments/evaluations. The course revisions are documented and shared.

Following Academic Year Following the Workshop Participation:

1. Implement revised course
2. Participate in class observation and feedback sessions
3. Participate in monthly Professional Learning Community meetings
4. Prepare a paper describing the revision process for each particular course, lessons learned, and outcomes of the revisions. The paper should be of a quality to be submitted to a professional conference or publication.

To date approximately 18% of our faculty have completed the summer program. The focus of our discussion is on the faculty who engaged in the summer intensive program since we have a broad range of data on those cohorts with which to best examine the impact of the Center's work.

Levels of Interaction

The Center opened in the summer of 2015, so at the writing of this paper we have been interacting with faculty for 2.5 years. One factor we consider when assessing the impact of our work is the level of interaction we have with each faculty member. We have broken the level of interaction into four levels: 1) No Interaction), 2) Low Interaction, 3) Medium Interaction, and 4) High Interaction. We use these categories to identify how much interaction a faculty member has with us. Figure 2 shows the breakout of the levels of faculty interactions across the last 2.5 years.

1. **Level 1 faculty, *No Interaction***, are faculty who are likely aware of the Center but have very limited or no direct interaction with us. Thirty percent of our faculty fall into this category.
2. **Level 2 faculty, *Low Interaction***, are faculty who interacted with us for 5 – 10 events a year. They have been involved enough to be aware of some aspects of the Center's work and have worked with the Center on some aspects of their instruction, but we do not have evidence of any changes in their classroom practices. Twenty-six percent of faculty fit within level 2.
3. **Level 3 faculty, *Medium Interaction***, are faculty who have interacted with us enough for us to know them by name and to be generally aware of their classroom practices and challenges. These are faculty who continue to interact with us across the year in substantive work. We are able to document changes in their classroom practices. Twenty-five percent of our faculty interact at a medium level.
4. **Level 4 faculty, *High Interaction*,** are faculty who have worked with us at intensive levels. The majority of this group have participated in the Summer Intensive Course Revision program, but others have been involved in more individualized coaching and guidance. We have evidence of changes in their classroom practices and student outcomes. Nineteen percent of our faculty are in the high interaction level.

These levels give us a sense of the extent of our reach across all faculty at Mines. Faculty were paid to participate in some of the events, other events included food (lunch or snacks), and some events had no monetary nor food enticements. The majority of the high levels of interactions provide some funding to faculty as these are usually initiative initiated by the institution and require a significant investment of faculty time.

Forty-four percent of our faculty have significant levels of interactions with the Center staff (levels 3 & 4). Over time, our goal is to move the majority of faculty to level two or higher, with minimal numbers of faculty at level 1.

This year, 2018-19, we anticipate an additional eighteen (18) faculty participating in the Summer Intensive program (moving them into Level 4). Eleven of the eighteen are currently categorized in Level 2 (low interaction) and three are in Level 1 (no interaction). Additionally, this spring and summer we have 38 faculty who will be engaged in a five-week online course (requiring a 10 hour per week commitment), which will move them into the high interaction level. Twenty-five of these faculty are in Levels 1 or 2. By August 2018, we anticipate 32% of our faculty will be engaged at a high interaction level and 28% at the medium interaction level. In all, 60% of our faculty will be at a medium interaction or higher three years after the opening of the Center. At medium interaction, faculty are beginning to use the Engineering Learning framework to shift the way they think and talk about teaching and learning.

Selection and Characteristics of the Cohort Faculty

Faculty submit an application to be part of the Summer Intensive program. In the first year, 46 faculty applied to the program and 29 were accepted and completed the program as the first cohort. Selection is based on funding (determines how many we can support) and impact of the course being revised (determined by factors such as the number of student reached, the sequence of course, if it is required versus elective), representation across the Departments, and qualitative assessment of potential for change in faculty practice. Thirty-five faculty submitted applications for the second cohort with 21 being accepted. Twenty-six faculty applied to the third cohort with 18 funded at this time. The characteristics of the faculty are outlined in Table 1.

Table 1. Characteristics of faculty in Summer Intensive by Cohort

	Cohort One	Cohort Two	Cohort Three	Total 1-3	Total %
Total faculty involved	29	21	18	68	
Departments represented (of 15 Departments)	11	10	10	12	80%
Tenure Track/Tenured faculty	6	14	10	30	44%
Teaching faculty	22	7	8	37	54%
Adjunct faculty	1	0	0	1	1%

Research Methods

Our research design utilizes mixed-methods approaches to assess the impact of faculty interacting with the Center. After intensive interaction with the Center, we expect to see faculty more consistently use the following in their course design and instructional practices:

- Coherent set of learning outcomes with aligned set of in-class tasks, out-of-class assignments, and assessments
- Placing more of the cognitive work in-class and out-of-class on the student (active learning)

- Continuous reflective cycle of data collection, analysis, and refinement of course design and instruction
- Continued learning and support through collaboration with colleagues and the Center

In other words, we expect faculty to make the Engineering Learning framework part of their practices. Ultimately, we expect to see a positive impact on student engagement and learning.

Data Collection

We have collected a variety of evidence to document changes in practices as well as to begin to understand the impact of these transformational practices on student outcomes. We have also examined university-level changes in policy and support for the Center and more broadly those that impact teaching and learning (e.g., faculty load formula, hiring criteria) to understand system level changes the work has catalyzed.

To understand changes in practices, we conducted syllabi analysis, classroom observations, and examined course artifacts.

- We gathered syllabi from all courses for faculty engaged in the summer program. The syllabi were gathered from the year before they began the program and the semester following their implementation of the course revision. Syllabi were analyzed for changes in articulation of learning outcomes, alignment of tasks and grading to those outcomes, and language in the syllabi (instructor-centered versus student-centered).
- We observed all faculty who participated in the summer program during the school-year before participation and then again each semester they taught following the summer program. We also observed a sampling of faculty who did not participate in the summer program, but were teaching sections of a course that was re-designed and being taught by a cohort faculty.

  We used an observation protocol that tracks classroom interactions in two-minute segments. The protocol was designed to specifically align with the Engineering Learning framework [17], [18]. The protocol is designed to monitor changes in instructor practices, ways in which students are working during class time, levels of cognitive demand of the tasks used in class [19], and alignment of the learning outcomes with the tasks. The last measure is an important aspect of Engineering Learning; a main component of Engineering Learning is the alignment of student activities, tasks, and assessments with learning outcomes.

  The levels we identified can also be aligned to Chi's framework [15], which identifies four stages of classroom task: passive, active, constructive, interactive. Developing innovative, creative thinkers with strong content knowledge and professional skills requires more constructive and interactive learning [13], [14], [15], [20]. As this is one of the foci of the summer intensive work, we look for this in classroom observations.

  In Spring 2017 and Fall 2017 we observed 93 classes. The courses represented classes from 15 different Departments and course levels as outlined below.
  1. 100 level classes = 33 courses revised and observed
  2. 200 level classes = 17 courses revised and observed
  3. 300 level classes = 25 courses revised and observed

4. 400 level classes = 13 courses revised and observed
5. 500 level classes (graduate level) = 5 courses revised and observed

The observation tool we designed captures how instructors are spending their time in class in relation to how students spend their time.

- Course artifacts were reviewed to consider alignment of tasks with the learning outcomes and for evidence of the integration of Engineering Learning (e.g., articulation of learning outcomes on the task sheets, embedded assessment, reflection points).

To begin to understand changes in student outcomes, we collected overall course grades for each course that was re-designed, conducted student surveys, utilized data generated by faculty (each developed a research project to assess the impact of their course changes), and conducted focused case studies.

- The course grades were pulled for sections of the course taught before the revisions and then each semester it was taught following the revision. For the first cohort, the post-revision data has been gathered for three semesters. The pre-revision grades were pulled for two years prior (if the course was taught during that time period) to consider variations in student populations[4].
- Student surveys were conducted at the end of redesigned courses taught by cohort one faculty during the Fall 2016 semester. Students were asked to report on their experience taking the course, how frequently the instructor used different pedagogical strategies, and perceived impact of the course on their learning. A total of 1,234 students participated in the survey.
- Faculty generated data and analysis provided greater insights into finer grained impacts. For example, in Chemistry, faculty were able to provide item analysis of questions on pre- and post-redesign exam items that differentiated between recall versus application questions.
- The case studies explored the impact on student outcomes at deeper levels and included interviews with faculty and deeper analysis of student performance on exams and projects.

The university level changes were analyzed by collecting and comparing policy documents (e.g., faculty handbook, procedures manual), meeting minutes (e.g., Faculty Senate, Board of Trustees), and budget allocations. These were analyzed to look for shifts in language, resources, and funding for teaching and learning, as well as Center initiatives.

Findings

Our finding are organized into four key areas:

- Leadership Support to Advance Teaching and Learning
- Faculty Move from Lecturers (covering content) to Designers and Facilitators of Learning
- Faculty Engage and Empower Students as Learners (active learning)
- Student Perform Better

---

[4] Students register or are placed into courses and sections based on schedules. Other than “lag sections” (students who are retaking a course out of sequence), there is no significant variance between course sections in our analysis comparing cohort to no-cohort classes.

Leadership Support to Advance Teaching and Learning

Institutionally, the President. Provost, Deans and the Board of Trustees provide strong support for the work of the Center. This is evident through their funding of 20-25 faculty to engage each summer in the intensive workshop, as well as in their commitment to staffing the Center (increased number of Center staff from one initially to currently eight full-time positions), funding faculty time for other professional learning opportunities, shared communication of the importance of teaching, and shifts in policies to promote instructional advancements. They all mark the importance of teaching in campus-wide presentations and at college-level presentations.

Faculty Move from Lecturers (covering content) to Designers and Facilitators of Learning

Using the observation protocol, we were able to document changes in classroom interactions and practices. In Year 1 (before Cohort 1 engaged in the summer intensive), 76% of the activities we observed in classrooms were on the low end of Chi's [15] learning activity framework. This means that that students were mostly passively receiving information. We saw an initial reduction by about 15% in student's being passive during class time in the first iteration of faculty's course revision (first semester of change). In the Spring and Fall 2017 semesters, the time spent passively was further reduced by 12% in Cohort 1 faculty's courses. During that same time period we saw a 5% reduction in passive time in Cohort 2 courses (Spring 2017 was pre-intensive and Fall 2017 was post- for Cohort 2). So we continue to see refinements and positive changes in the courses a year out from the summer intensive. We anticipate changes will continue for several years and are planning to observe cohort classes over a five-year period.

Additional changes in classroom interactions include an eight percent (8%) reduction in time spent as whole group with that time being allocated for individual or small group tasks during class time. Faculty lectured sixteen percent (16%) less than they did before engaging in the course redesign effort. We also see an increase (42% to 71%) in the number of classes where the vast majority of the students (76-100% of the students) actively engage in the course work across all of the courses that apply Engineering Learning.

An analysis of course syllabi and artifacts (assignments, student work samples) show that after completing the intensive work with the Center, faculty organize out-of-class work for students that placed less emphasis on studying for a test and instead focused more on sense-making activities, writing, use of labs, small group project work, and watching videos as compared with non-Cohort classrooms and prior semester for the same instructor. We also see a significant shift in the alignment of the tasks with the learning outcomes (55% of courses to 63%).

Faculty Engage and Empower Students as Learners (active learning)

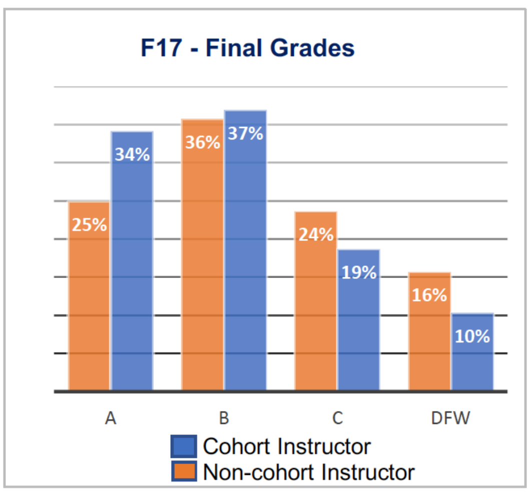
Pre-post observation data points to changes in faculty practices, with faculty universally using more active learning in their courses after participating in the summer intensive. Additional changes in classroom interactions include an eight percent (8%) reduction in time spent as whole group with that time being allocated for individual or small group tasks during class time. Faculty lectured sixteen percent (16%) less than they did before engaging in the course redesign effort. We also see an increase (42% to 71%) in the number of classes where the vast majority of the students (76-100% of the students) actively engage in the course work across all of the courses that apply engineering Learning.

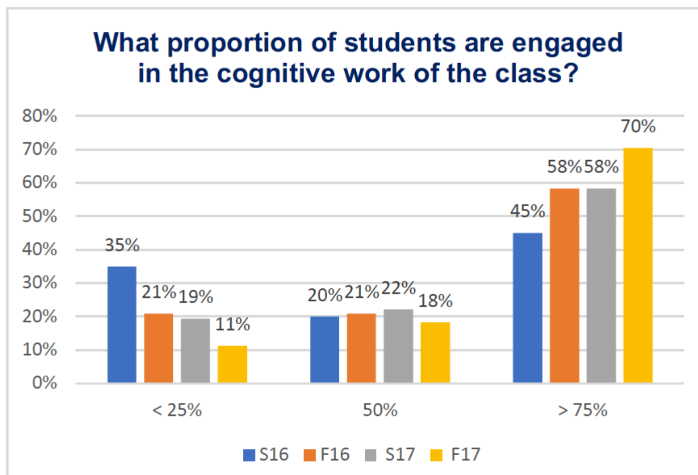
Students Perform Better

In courses revised by participants in the intensive program (Cohort faculty), we see statistically significant enhancements in grades and in performance of higher-order cognitive tasks. These enhancements consistently show up in pair-wise comparisons of courses with multiple sections (with and without Cohort instructors) and common assessments, as well as in looking at pre- post measures across the same faculty member. Data from a course with a large number of sections show a significant gain in grades of A and a reduction in grades of D or F and in students withdrawing from the course (DFW) comparing Cohort to non-Cohort sections (Figures 2 and 3).

There is also a positive shift in student performance in higher cognitively demanding tasks and assessments. Faculty shared their observations of students moving to more sophisticated reasoning and articulation during discussions, in responses to questions, and in written assignments. This is further documented in analysis of common exams comparing item analysis and Cohort versus non-Cohort sections (Figure 4).

Cohort sections performed higher than non-cohort sections on all questions of common exams in Chemistry, with smaller but notable increases on lower cognitively demanding questions. As we report in other papers [18], [21], overall (aggregate) and in individual classes we see significant enhancements to student outcomes. The enhanced outcomes include academic performance regarding assessment of content knowledge, an enhancement in professional skills (e.g., discourse, reasoning, argumentation), and student perceptions of the classes.





Figures 2 and 3. 2: Grade distribution by Cohort and Non-cohort sections. 3: Shifts in proportion of students engaged in the cognitive work during class time from Spring 2016 – Fall 2017.

Student survey data from introductory courses taught by Cohort faculty reflects a generally positive response to the learning environment. Compared to students enrolled in non-redesigned courses, students in redesigned courses were more likely to agree in course surveys that "I look forward to coming to this course" (average 3.5 versus 3.2 on a 5 point-scale) and that "This course really makes me think" (average 4.3 versus 3.8 on a 5-point scale).

Conversely, student data from upper level courses reflects more resistance to the changes in classroom practice. In those instances, students noted negative comments in end-of-course surveys and complained to instructors that they are being asked to do more during class time than other sections or past semester students. During one group interview, students noted that they could not do their homework for other classes during this course anymore because they were doing so much during class time. They did admit that they were learning more, but just did not like that it was different. We anticipate this will be less of an issue as more of the courses across campus require engage students during class and student expectations change.

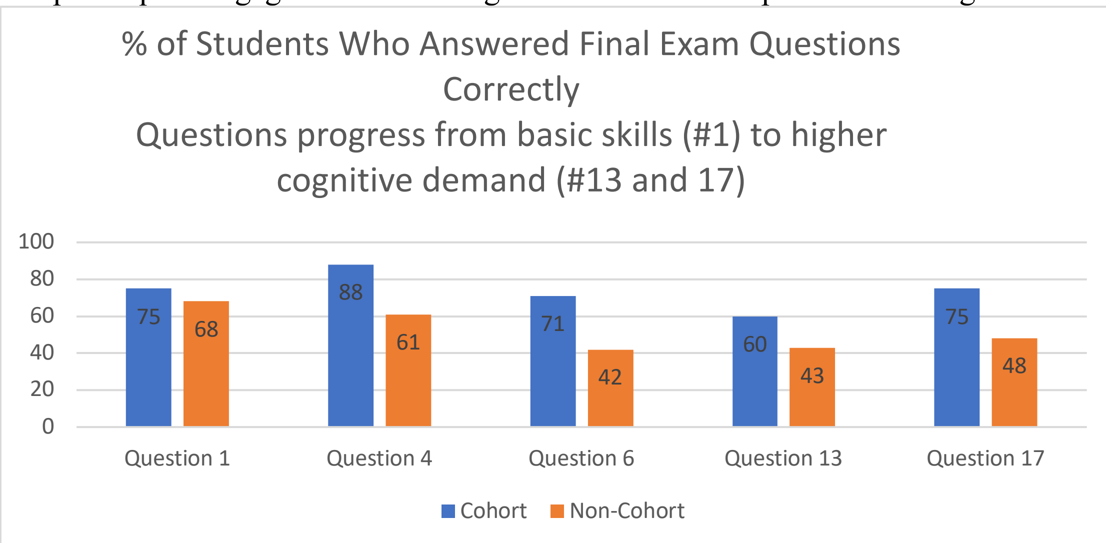


Figure 4. Pair-wise comparison of student performance on varying cognitive demand questions comparing Cohort and non-Cohort sections.

Interestingly, sections where students noted concern about doing more during class time outperformed the other sections on common exams or in comparison to past semesters with common assessments. For instance, in a course where several students commented negatively about the course design, on common exams (a midterm and final) compared to three other sections taught in the more traditional format (non-Cohort), students in the Cohort faculty's section scored on average 4% above the other sections.

Changes in Perspectives about Courses: Changing the Conversation

As they engage with the Center, faculty shift their perspective from one of covering content to thinking about how to engineer learning in their courses. They focus on student learning, student outcomes, and alignment of the work students do to the outcomes. We see this shift in an analysis of syllabi pre- and post-intensive work, an analysis of course assignments from revised courses, and in interviews with faculty conducted in January 2018 by an external evaluator. For instance, one faculty member reported:

> *Probably the biggest benefit of the workshop was that it simply opened my eyes to a lot of issues that I was never aware of. By that I mean different forms of assessment, the importance of closing the loop with assessment back to your learning outcomes, having deliberate learning outcomes, and designing activities and assessments to specifically achieve those goals rather than just having wishy-washy ideas about basically what topics a class should cover* (Faculty member C1-A)

This Cohort 1 faculty member noted a shift in perspective towards a clear focus on learning outcomes. Another Cohort faculty similarly noted:

> *In my classes now, I emphasize how important the actual learning is and what they're going to take on, what they're going to take from this into their future careers. I'm thinking about if the students are actually transforming and learning a lot throughout the class, rather than just getting through it.* (Faculty member C1-C)

We now hear the faculty using the terminology and patterns of the Engineering Learning framework. It has now become a mantra for some faculty answering most questions about their course as "well of course we first think about the learning outcomes." As they align their practices with Engineering Learning, faculty are becoming more student centric. For example:

> *I just feel like I love my class now. It's just way better. It's fun. It's way better than lecturing. I feel like, in general, students are learning better. I get to know my students better. I just feel like it's better all around.* (Faculty member C2-A)

Not surprisingly, not all of the shift in perspectives is positive. Some faculty still struggle as they try to align their new learning with old beliefs and actions. For example, several faculty members struggle with their beliefs about what "teaching" means and the role of the instructor. Some grew up in a time or culture where teaching and lecturing are synonymous. It is hard to separate lecturing from teaching. Our institution still calls courses "lectures."

> *It's complicated. I have many days when I would have the feeling I just did not teach anything in that class. It was hard to get away from feeling that need to lecture. I think I'm decent at it, and if I'm not telling the students these little things, then it is hard to tell if the students are "getting it", which is unsettling on my part.* (Faculty member C1-D)

Conclusion

Taken together, the data suggest that the framework of Engineering Learning is influencing faculty course design and instructional practice, as well as student outcomes. Additionally, we have evidence that these new practices, framed by Engineering Learning, are positively shifting the conversations faculty have around teaching and learning. These shifts in classroom practice, student outcomes, and the way faculty think about teaching are all within a context of institutional support. While this preliminary data is encouraging, we also see challenges individual faculty face as well as institutional challenges to this work. Time is a significant constraint. Many faculty—particularly tenured faculty—do not have a full summer month to commit to course redesign. To address this challenge, we are developing new modes to work with faculty at intensive levels, but that do not require a month-long commitment in the summer.

Another challenge faculty face is the cultural challenge of changing learning from sit and get to active involvement. We know this kind of deeper learning is critical for success in future work, but change is slow. This is a common challenge across universities. This paper provides some insights into how we have begun to tackle the challenge. While many other universities can't commit to funding 30% of its faculty for a month to participate in professional development, the design of the program can provide insights into smaller interventions. We are working on short-courses, workshops, online studies, and other approaches utilizing the Engineering Learning framework to guide institutional transformation to enhance teaching and learning.

REFRENCES:

1. Miller, Seumas, "Social Institutions", The Stanford Encyclopedia of Philosophy (Winter 2014 Edition), Edward N. Zalta (ed.). 2014. [On line]. Available: https://plato.stanford.edu/archives/win2014/entries/social-institutions/ [Accessed January 27, 2018].
2. KE Weick, “Educational Organizations as Loosely Coupled Systems,” *Administrative Science Quarterly*, vol. 21, No. 1, (Mar., 1976), pp. 1-19. 1976. Available: http://www.jstor.org/stable/2391875 Accessed: 24/06/2008 06:28
3. KE Weick, *The Social Psychology of Organizing. Second Edition*. Addison-Wesley Publishing Company. Menlo Park, CA. 1979.
4. JC Lammers & JB Barbour, “An Institutional Theory of Organizational Communication,” *Communication Theory*, 16: 356–377. 2006. doi:10.1111/j.1468-2885.2006.00274.x
5. RL Daft, *Organization theory and design*. Mason, Ohio: Thomson/South-Western. 2004.
6. SA Spiegel, SA Claussen, R Falconer, & AG Caster. “Insights into Systemically Transforming Teaching & Learning at the Colorado School of Mines.” ASEE 123rd Annual Conference and Exposition. New Orleans, LA. June 26-29, 2016. Downloaded on March 12, 20178 from: https://www.asee.org/public/conferences/64/papers/15298/view
7. T O’Banion, “Focus on Learning: The Core Mission of Higher Education.” *League for Innovation.* 2010. Downloaded on 01/15/2018 from: http://www.jsu.edu/redballoon/docs/1O_Banion-Focus_on_Learning_Final.pdf
8. HA Simon, HA. “The Job of a College President.” *Educational Record*, Winter 1967, Vol. 48, pp 68-78.
9. SA Spiegel, *Engineering Learning.* 2017. Downloaded on 02/07/2018 from: https://trefnycenter.mines.edu/pedagogy-resources/engineered-learning/
10. GP Wiggins & J McTighe. *Understanding by design*.), Princeton, NJ: Association for Supervision and Curriculum Development (ASCD). 2007.
11. SA Ambrose, M Lovett, MW Bridges, M DiPietro, & MK Norman. *How learning works: Seven research-based principles for smart teaching*. San Francisco, CA: Jossey-Bass. 2010
12. JB Biggs & C Tang. *Teaching for Quality Learning at University*. New York, NY: McGraw-Hill/Society for Research into Higher Education/Open University Press. 2011.
13. J Bransford, AL Brown, RR Cocking, & National Research Council (U.S.). *How people learn: Brain, mind, experience, and school*. Washington, D.C: National Academy Press. 2000
14. RM Felder & R Brent. *Teaching and learning STEM: A practical guide*. San Francisco, CA: Jossey-Bass. 2016
15. MT Chi. “Active-constructive-interactive: A conceptual framework for differentiating learning activities.” *Topics in Cognitive Science*, 1(1), 73–105. 2009.
16. S Loucks-Horsley, N Love, KE Stiles, S Mundry, PW Hewson PW. *Designing professional development for teachers of science and mathematics.* Thousand Oaks, CA: Corwin Press, 2003.
17. T Tolnay, SA Spiegel, & JZ Sherer. Development and Use of the Engineering Learning Classroom Observation Tool (ELCOT). 2017. ASEE Annual Conference and Exposition. Columbus, OH. June 245-18, 2017. Downloaded on March 12, 2018 from: https://www.asee.org/public/conferences/78/papers/18454/view

18. SA Spiegel, M Sanders, & JZ Sherer. Moving Beyond Active Learning to Engineering Learning: An Approach to Course Design and Enactment. 2018. ASEE Zone IV conference, Boulder, CO. March 25-27, 2018.
19. N Webb. Research Monograph No. 18: “Alignment of science and mathematics standards and assessments in four states.” Washington, D.C.: CCSSO. 1999
20. M Prince. “Does Active Learning Work? A Review Of The Research,” *Journal of Engineering Education*, 93(3), 223-231. 2004.
21. M Sanders, SA Spiegel, & JZ Sherer. Moving Beyond “Does Active Learning Work?” with the Engineering Learning Observation Protocol (ELCOT). 2018 ASEE National Conference and Exposition. Salt, Lake City, UT. June 23-27, 2018.