

## **Scaling a Faculty Professional Development Program to Multiple Disciplines through Disciplinary Communities of Practice Evolving from Evidence-Based Workshops**

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Stephen Krause is professor in the Materials Science Program in the Fulton School of Engineering at Arizona State University. He teaches in the areas of introductory materials engineering, polymers and composites, and capstone design. His research interests include evaluating conceptual knowledge, misconceptions and technologies to promote conceptual change. He has co-developed a Materials Concept Inventory and a Chemistry Concept Inventory for assessing conceptual knowledge and change for introductory materials science and chemistry classes. He is currently conducting research on an NSF faculty development program based on evidence-based teaching practices. The overall goal is to develop disciplinary communities of practice across the college of engineering. The approach is being promoted through semester-long faculty workshops and then through a semester of supported implementation of faculty classroom innovations. Changes in faculty beliefs and classroom practice should positively impact student performance and retention. He was a coauthor for the best paper award at the FIE convention in 2009 and the best paper award in the Journal of Engineering Education in 2013.

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Robert J. Culbertson is an Associate Professor of Physics. Currently, he teaches introductory mechanics and electrodynamics for physics majors and a course in musical acoustics, which was specifically designed for elementary education majors. He is director of the ASU Physics Teacher Education Coalition (PhysTEC) Project, which strives to produce more and better high school physics teachers. He is also

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His research takes two distinct but interrelated paths focused on elementary students' learning in science and engineering as well as in-service science teachers' professional development. The first focus involves how language as a learning tool improves students' conceptual understandings, literacy, and representation competencies in science. His second research focus is on how in-service teachers develop their knowledge for teaching science and engineering in argument-based inquiry classrooms. This research is aimed at developing measures of teachers' Pedagogical Content Knowledge (PCK) for adopting the argument-based inquiry approach, as well as developing tools to capture the interactive nature of PCK.

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Lindy Hamilton Mayled is a PhD candidate at Grand Canyon University. She is pursuing her PhD in Psychology of Learning, Education, and Technology. Her background is in K-12 education where she has served as a high school science teacher, Instructional and Curriculum Coach, and Assistant Principal. Her research and areas of interest are in improving STEM educational outcomes for Low-SES students through the integration of active learning and technology-enabled frequent feedback. She currently works as the Project Manager for the NSF faculty development program based on evidence-based teaching practices.

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Elizabeth Lopez is a Master's student at Arizona State University studying biomedical engineering. She has undergone the undergraduate engineering curriculum and has facilitated the implementation of evidence-based instructional strategies in the biomedical senior design course. In JTFD, she has evaluated and analyzed the shift in instructor fidelity towards student-centered learning.

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Bethany Smith is currently pursuing her PhD in materials science and engineering at University of California, Berkeley. She has been involved in STEM education research since 2012 under the direction of Professor Stephen Krause. Her research interests in STEM education include faculty development, best classroom practices, and improving undergraduate engineering student retention through understanding what makes students leave engineering.

# **Scaling a Faculty Professional Development Program to Multiple Disciplines through Disciplinary Communities of Practice Evolving from Evidence-Based Workshops**

## **Abstract**

For more effective teaching and learning in undergraduate engineering education, there is a strong need for faculty professional development to instruction from instructor-centered, information-transmission teaching by lecture to more student-centered, conceptual-change learning by active learning through student engagement. The National Science Foundation IUSE (Improving Undergraduate STEM Education) program has funded a large-scale faculty development program at a large southwestern university called Just-in-Time-Teaching with Two Way Formative Feedback for Multiple Disciplinary (JTFD) Programs. The project scales to seven engineering disciplines with 84 faculty using a train-the-trainer model to engage faculty in year-long apprenticeships with a semester of eight biweekly workshops followed by a semester of six biweekly mentor-supported classroom innovation implementation. Prior project research has shown that evidence-based practices such as student engagement, contextualization of content, and two-way formative feedback can improve student attitudes, achievement and persistence. Research also shows that changing faculty teaching beliefs toward evidence-based strategies and practices can be difficult, but the transition can be eased when disciplinary communities of practice support faculty while they are changing their beliefs and practices. The personal interactions that occur within and between the disciplinary communities of practice are being characterized in JTFD with social network analysis (SNA) and will be correlated to shifts, across time, in the beliefs and practice of the faculty toward student-centered instruction. Prior project SNA research has shown faculty who are socially better connected to one another also teach with more student-centered classroom practices, as found from classroom observations. This was assessed by a tool called Reformed Teaching Observation Protocol (RTOP) which has 25 items related to evidence based practice and is used by trained observers to assess classroom practice. Faculty beliefs and classroom practice are being assessed in JTFD with surveys, open ended questions and classroom observations. Faculty motivation is being assessed with a new survey using expectancy-value theory. The impact of faculty changes in classroom practice results have been collected during the spring 2016 term from four pairs of disciplinary leader trainers who completed the eight workshops. One result showed that the effect of the eight workshops on faculty's student-centered classroom practice, as measured by RTOP, was an improvement between 34% and 65%. Another result showed that, for two faculty, compared to the same class for a prior semester, significant gains in the student grade ratio (the ratio of A's plus B's to C's plus D's plus E's plus W's). Thus, the cohort of eight faculty trained during the Spring 2016 semester shifted their practice significantly from teacher-centered instruction to student-centered learning as shown by the classroom observation RTOP results. Because of the limited number of participants other measures of change in faculty beliefs and motivation were positive, but did not show statistical significance. Future cohorts with larger numbers of participants can reveal correlations between faculty beliefs, motivation and classroom practice.

## Introduction

Research has shown that instruction through student engagement is more effective than traditional knowledge transmission through lecture<sup>1,2</sup>. Today, however, most instructors teach as they were taught, by information transmission through lecture. As such, the challenge then becomes how to promote a shift in instruction from faculty-centered teaching to student-centered learning. In order to facilitate such a shift, creating materials for adaptation to student engagement teaching is not sufficient because there needs to be a shift in faculty beliefs about instruction. This shift needs to help move instructors from viewing themselves as disseminators of knowledge and concepts to facilitators who help students learn the desired knowledge and concepts through student engagement. As such, a means to promote this shift has been the creation of a faculty development program. Such a program has been funded by the National Science Foundation IUSE (Improving Undergraduate STEM Education) program for large-scale faculty development program at a large southwestern university called Just-in-Time-Teaching with Two Way Formative Feedback for Multiple Disciplinary (JTFD) Programs. The project scales a previous, smaller single disciplinary development program, Just-in-Time Teaching with Frequent Formative Feedback (JTF)<sup>3</sup>, to seven engineering disciplines with 84 faculty. The seven disciplines include aerospace (AE), biomedical (BME), chemical (CHE), civil, (CEE) materials (MSE), and mechanical engineering (ME), as well as construction (CON). It uses a train-the-trainer model to engage faculty in year-long apprenticeships with a semester of eight biweekly workshops followed by a semester of six biweekly mentor-supported, disciplinary community-of-practice (CoP) classroom implementation biweekly discussions.

In the earlier JTF collaborative project seven materials science faculty participated in the program over a four-year period. The guiding principles of the project were based on the research findings described in the book, *How People Learn (HPL)*.<sup>4</sup> The book described how cognitive processes act to achieve learning through conceptual change. For more effective learning, instructors need to: 1) elicit students' prior knowledge to inform instruction; 2) engage students to promote conceptual change so they can construct deep knowledge organized in a conceptual framework; and 3) encourage metacognition to build habits of expert learners who define their learning goals and monitor their own progress. These principles were realized through student reflection, student engagement, and contextualization of concepts by linking abstract concepts to real-world concrete examples. The positive impact of this approach of faculty beliefs was shown with a survey taken after three years on the project. It found that eight out of eight faculty said, in the last two years of using JTF pedagogy, their classroom practice had "changed somewhat or changed significantly." One quote illustrating this was, "I teach using full engagement strategies.... previous classes were much more lecture-centric." Another question showed that 7 of 8 felt that their views about teaching had changed "somewhat or significantly." On an open-ended survey faculty were queried, "How do you view your role in the classroom now as compared to before joining *JTF*?" Some responses to this question were:

- "More as a coach and encourage and guide the students to do the necessary mental gymnastics to improve their comprehension and mastery of the topics."
- "More of a guide now."
- "More of a coach than a 'lecturer'."

- "I've always taken a role in class as a mentor/coach rather than a lecturer."
- "I realize even more that I am the guide and they must take on the learning."

The impact on students' attitude, persistence and achievement was also very positive. One quote from a student reflection was, "Muddiest Point items are a powerful tool that shows a teacher where students are not understanding all information." Results for student persistence showed that, across collaborating institutions, persistence was 95% to 97% for 938 students over 9 classes across two semesters. The impact on grades was also quite positive. Comparing grade distributions for four instructors after three years of using JTF pedagogy resulted in a positive grade shift of a half to a full grade average. Also, D's and E's were reduced by more than 50%. During the four years of the program the participants met on a monthly basis during the academic year and also participated in three retreats during the same time. As such, the participants formed a community of practice (CoP) centered around teaching of introductory materials science courses. The combined effect of implementing the JTF pedagogy and development of a materials science CoP resulted in shifting of faculty beliefs and classroom practice from instructor-centered teaching toward student-centered learning resulted in positive outcomes of student attitude, achievement and persistence. Scaling this approach was used in developing the JTFD project.

As previously stated, JTFD scaled the JTF project to seven engineering disciplines with 84 faculty using a train-the-trainer model. As such, the JTFD project objectives include: shift faculty beliefs, strategies, and practice toward student-centered learning; assess faculty fidelity of implementation of engagement, reflection, and feedback pedagogy; develop sustainable disciplinary communities of practice through the faculty development program; and assess the effect on student achievement and persistence. The background and some preliminary data on the project will now be discussed.

## **Background**

### **Facilitating Shift of Faculty Beliefs toward Student-Centered Learning**

There are a number of different models of personal change processes in innovation that have been used in different fields such as public health, agriculture, and have also been applied in engineering education<sup>5</sup>. One model is *diffusion of innovation (DOI)*, based on a book of the same title published by Rogers, now in its 5th edition.<sup>6</sup> The approach has been summarized with a framework of a five stage model of adoption of innovation. The stages include:

1. Knowledge or Awareness - occurs when an individual is exposed to an innovation and its functioning
2. Persuasion or Interest – occurs when interest is growing and an individual seeks additional information
3. Evaluation and Decision – occurs when an individual decides to adopt or reject an innovation
4. Implementation or Trial – occurs when an innovation is tested by putting it into use
5. Confirmation or Adoption – occurs when use of an innovation is continued and sustained

Researchers have found that the model may be successful at the first two stages of *awareness* and *interest*, but sometimes fail at the *trial* stage, which they say can lead to decreasing effectiveness or discontinuing use of an innovation<sup>5</sup>. However, there is also evidence that suggests that, providing support for implementing innovation in the third and fourth *decision* and *trial* stages, with personal or small group interactions, such as a CoP, can provide a more successful progression to the higher stages of diffusion of innovation.<sup>7</sup> Pimmel, et al.<sup>8</sup> used a virtual community of practice (VCP) implementation of Rogers' *DOI* model for faculty development using the internet. After training a group of faculty leader pairs they, in turn, trained disciplinary groups of 20 – 30 faculty participants. They used evidence-based instructional strategies (EBIS), methods, and examples, for a half semester where faculty participants progressed through the first and second stages of *awareness* and *interest* in Rogers' *DOI* model. To get through the the third and fourth stages of *evaluation* and *implementation* of the *DOI* model, a semester of supported classroom implementation was used with discussions about classroom innovation successes and barriers and strategies to overcome them. Positive results were found for the VCP model and a similar approach is used in the JTFD project.

### **Facilitating Spread of Innovation in an Organization with a Community of Practice**

A community of practice (CoP) has been defined by Wenger et al.<sup>9</sup> as a unique combination of three elements: a *domain of knowledge* given by a set of issues; a *community of people* who care about this domain; and the *shared practice* in which they are engaged in learning and improving in their domain. In a panel session in FIE in 2003,<sup>10</sup> *Communities of Practice in Engineering Education*, a question that was posed was, "How does a member of an organization gain the *insider knowledge* to learn how to act, talk, and think like a successful practitioner?" Brown and Duguid<sup>11</sup> suggest that, "Learning that is informal, social, and focused on meaningful problems helps create *insider knowledge*." Gaining *insider knowledge* is a major part of becoming a member of a CoP. In the JTFD project, there are disciplinary CoPs that are overseen by previously trained faculty disciplinary pairs who had become the *insiders* who had implemented student-centered learning in their own classrooms. They are facilitating discussions of the disciplinary faculty cohorts on their implementation successes, issues, and strategies to improve effectiveness of implementation JTFD strategies. They are coming together to create a new level of organization--a *new* community with novel ways of practicing and interacting by being pragmatic in working together to solve implementation problems in teaching, assessment, and evaluation. This promotes the *spread* of innovation across the disciplinary CoPs. At the same time, the CoPs are promoting *deeper change in faculty beliefs* and potential for *sustainability of innovation*.

### **Structure of the Faculty Development Program**

The program is similar to the Pimmel et al.<sup>8</sup> "train-the-trainer" model. Here, *JTFD* project faculty provide a round of a two-semester program for each of a Cohort 1 (AE, ME, CE, and CON) and a Cohort 2 (BIO, CHE, and MSE), Tier 1 Disciplinary Leader Pairs (DLPs). After that, each Tier 1 DLP trains their own Tier 2 Disciplinary Faculty Groups (DFGs) composed of 8-12 faculty each. Thus, in Year 1, Cohort 1, Tier 1 DLPs, (AE, ME, CE, and CON) are trained and assessed by project faculty in an 8-week biweekly semester program on evidence-based instructional

strategy and JTFD pedagogy. Because of the limited time for this first cohort of DLPs during spring 2016 semester, they also implemented innovations in their classrooms during the same term with support of project faculty. In project Year 2 the Cohort 1 (AE, ME, CE, and CON), Tier 1 DLPs then train their own Tier 2 disciplinary faculty groups, by replicating training and classroom implementation they received previously. The Tier 1 DLPs are building their own disciplinary CoPs with their Tier 2 DFGs and providing support during training and implementation. Also in Year 2, project faculty are training the Cohort 2 set of Tier 1 DLPs (BIO, CHE, and MSE) in the same way used for Cohort 1 DLPs. Then, the following year, those Cohort 2 (BIO, CHE, and MSE), Tier 1 DLPs will each train their own Tier 2 DFGs, by replicating the training and classroom implementation they received. The overall details and schedule for the Tier 1 and Tier 2 "train-the-trainer" model are shown in Table 1.

**Table 1. Training Schedule for Disciplinary Leader Pairs and Disciplinary Faculty Groups**

	Cohort 1 Tier 1 <i>Disciplinary Leader Pairs (DLPs)</i> AE, CHE, ME, MSE	Cohort 1 Tier 2 <i>Disciplinary Faculty Groups (DFGs)</i> AE, CHE, ME, MSE	Cohort 2 Tier 1 <i>Disciplinary Leader Pairs (DLPs)</i> BME, CE, CON	Cohort 2 Tier 2 <i>Disciplinary Faculty Groups (DFGs)</i> BME, CE, CON
Year 1 F15 - Sp16	Being Trained by <i>Project Leaders + Classroom Implementation</i>			
Year 2 F16 – Sp17	Follow-on Assessment of DLP Faculty Individuals' Classroom Practice	Being Trained by <i>Discipl. Leader Pairs + Classroom Implementation</i>	Being Trained by <i>Project Leaders + Classroom Implementation</i>	
Year 3 F17 – Sp18		Follow-on Assessment of DFG Faculty Individuals' Classroom Practice	Follow-on Assessment of DLP Faculty Individuals' Classroom Practice	Being Trained by <i>Discipl.. Leader Pairs+ Classroom Implementation</i>
Year 4 F18 – Sp19				Follow-on Assessment of DFG Faculty Individuals' Classroom Practice

The topics for the first semester 8-week workshop training are based on EBIS and JTFD pedagogy with sessions that link research to practice and include the following:

1. Introduction to Active Learning and Disciplinary Communities of Practice
2. Bloom's Taxonomy and Writing Effective Learning Objectives
3. Pedagogies of Engagement I: Making Class Sessions More Interactive
4. Pedagogies of Engagement II: Implementing Active Learning in the Classroom
5. Pedagogies of Engagement III: Cooperative Learning – Structured Teams
6. Motivation and Learning
7. Promoting Inclusive Practices in the Classroom
8. Muddiest Points and Other Tech Tools; Facilitating Course Innovation

### **Project Evaluation Methodology**

Evaluation includes both formative and summative components and aligns with project objectives. Data from engineering faculty and their students is providing information about the extent to which classroom practice is changing and about the impact on student persistence and achievement. Determining the degree to which faculty beliefs have changed is a measure of the extent to which an innovation can potentially be sustained. Two frequently used tools to measure extent of change of faculty beliefs are the Approaches to Teaching Inventory (ATI) survey and

the Reformed Teaching Observational Protocol (RTOP). The ATI is a self-reporting tool designed by Trigwell and Prosser<sup>12</sup> that is a valid and reliable tool that measures the extent to which faculty teach with an approach toward instructor-centered knowledge transmission versus student-centered conceptual change. The RTOP is a classroom observational protocol that quantitatively characterizes the extent to which faculty implement EBIS student-centered behaviors in their own classroom practice<sup>13-15</sup>. Also, a new survey has been developed to measure faculty motivation towards implementing three key classroom strategies, contextualization of content, student to student interactions, and student reflection. The survey uses expectancy-value theory and is called VECTERS (Value, Expectancy, and Cost of Testing Educational Reforms)<sup>16</sup>. The personal interactions that occur within and between the disciplinary communities of practice are being characterized in JTFD with social network analysis (SNA) and will be correlated to shifts, across time, in the beliefs and practice of the faculty toward student-centered instruction. Prior project SNA research has shown faculty who are socially better connected to one another also teach with more student-centered classroom practices, as found from classroom observations<sup>17</sup>. Pre-post assessments of ATI, VECTERS, RTOP and SNA at the beginning baseline training semester and at the end of the classroom implementation semester allows the project team to evaluate the extent to which instructional strategies have shifted toward student-centered learning. Comparison of these results to those of student persistence and achievement is being related to the impact that faculty development and the associated impact will be having on student performance. Cumulative feedback results from the seven disciplinary communities of practice will be used to elicit information about barriers to implementation and is being used to subsequently revise faculty training. The evaluation framework in Table 2 provides a set of questions and data sources for *JTFD*. This framework is being revisited periodically by the team to ensure that the questions continue to be relevant. Additional questions and data collection methodologies are being added as needed.

**Table 2. Evaluation Framework**

<b>Types of Changes</b>	<b>Questions</b>	<b>Data Sources</b>
Changes in faculty beliefs and attitudes about teaching and student learning	Are faculty embracing the principles of How People Learn in implementing EBIS & <i>JTFD</i> ? Are their beliefs shifting toward student-centered learning?	ATI for faculty beliefs; VECTERS for faculty attitude on motivation for teaching change
Changes in faculty classroom practice and resources	Are faculty using their training to modify their classroom instruction toward engagement and creating learning activities and resources?	Faculty surveys; RTOP for change in classroom practice created for students
Changes in student persistence and achievement	Is student persistence improving? Is student learning improving as a result of <i>JTFD</i> instructional strategies?	Student persistence, class start to end (# present final / # present 3rd week); Student learning with fraction DFW and final grade distribution.
Changes in how faculty communicate and collaborate	Are disciplinary program communities of practice being developed / nurtured / sustained?	Social network analysis; faculty surveys; disciplinary CoP meeting notes
Awareness and changes in faculty beyond <i>JTFD</i>	Are non-project faculty who have learned about this project interested in or using <i>JTFD</i> web tools & resources, materials, and strategies in their classrooms?	Project faculty surveys on discussion of <i>JTFD</i> with others; web or other tools adapted by other programs or universities

## **Structure and Content of Workshops**

Each year's program consists of a semester of workshops followed by a semester of supported implementation discussions within each disciplinary community of practice. The topics for the first semester 8-week workshop training are based on evidence-based instructional strategies and JTFD pedagogy with sessions that link research to practice. First, the subject for each week was determined, and a time management schedule was created. Then readings, web sites, and videos were selected for each workshop. The project members developed PowerPoint presentations, which went through a thorough review process. Throughout the planning process, project members were purposeful in selecting readings and developing presentations that would engage faculty to promote student-centered learning strategies. As previously discussed, the workshop topics include the following:

1. Introduction to Active Learning and Disciplinary Communities of Practice
2. Bloom's Taxonomy and Writing Effective Learning Objectives
3. Pedagogies of Engagement I: Making Class Sessions More Interactive
4. Pedagogies of Engagement II: Implementing Active Learning in the Classroom
5. Pedagogies of Engagement III: Cooperative Learning – Structured Teams
6. Motivation and Learning
7. Promoting Inclusive Practices in the Classroom
8. Muddiest Points & Other Tech Tools; Facilitating Course Innovation

Each workshop consisted of an introduction, brief discussion of homework results, a short mini-lecture on the main topic, a breakout with discussion of concepts along with a few relevant open-ended questions, then followed by a report out from each group (usually two or three) to all participants. A short wrap up completed the workshop. Report outs were recorded on white boards to facilitate communication and to present comments and highlights. Initially the workshops were planned for 90 minutes, but during the first session about half of the faculty present had to leave due to class obligations, so session durations were reduced to 60 minutes. This generally worked fine, but stricter time management was required, which sometimes limited discussions to shorter, more focused contributions. Preparation (or homework) for each workshop consisted of one or two short readings from the research literature and plus a reference to one or two web sites and/or videos. Participants also had a short homework which was to be completed the day before the workshop for brief discussion at the start of the next workshop.

## **Structure of Supported Implementation Community of Practice Discussion Sessions**

The second semester in each yearly program consists of six biweekly supported implementation discussions within each disciplinary community of practice. The topics are based on short refresher notes from earlier workshops in and a few key critical open-ended questions related to implementation of innovations in classroom practice. Those topics include:

1. Opportunities and Issues in Implementation of Bloom's Taxonomy and Active Learning
2. Assessing Student-Centered Learning vs. Instructor-Centered Teaching
3. Implementation of Tech Tools and Impact of Summative and Formative Assessment
4. Discussion of Observations of Active Learning Classrooms of Project Leaders

5. Implementation of Cooperative Learning and Motivation
6. Implement Wrap-up of Faculty Beliefs, Instructor Role in Classroom, & Value of CoPs

Each CoP discussion session has a short handout and PowerPoint with refresher materials from the first semester workshops along with some key open-ended questions related to participants' viewpoints and reports on implementing innovations in their classrooms. At this time of submission the discussions are ongoing so there is only limited data from these sessions.

### **Preliminary Results and Discussion**

Preliminary results are reported for this first year of the project, when we recruited 8 faculty members, who were pairs from 4 disciplinary programs (AE, ME, CE, and CON). This initial group of 8 faculty leaders, or Cohort 1, then became the Disciplinary Leader Pairs (DLPs) who are training each group of faculty from their own discipline (Cohort 1, Tier 2). During the first semester of the first year, the project leadership team developed and refined materials for the workshops, including creating a Blackboard site, presentations for each workshop, and readings, web sites, and videos to support each session. Each of the workshops focused on different aspects evidence-based instructional strategies (EBIS) and JTFD pedagogy. During the second semester of the first year the Cohort 1, Tier 1 disciplinary pairs were trained during workshops and implemented the innovations in their own classrooms during that semester. The main source of data from that semester was from classroom RTOP observations. The ATI was administered to study change in faculty beliefs and the VECTERS instrument was given to look at motivation and positive trends were shown, the data was not statistically significant because of the limited number of participants. Data collected from Cohort 1, Tier 2 participants should be better because there are over 30 participants enrolled in the program during Fall 2016 and Spring 2017. Attendance for the first semester of Fall 2016 has been over 80% and survey result submission has been greater than 75% which should provide sufficient data for analysis.

### **Classroom Implementation Assessment**

In order to evaluate changes for the 8 Cohort 1, Tier 1 in faculty instruction, techniques, and implementation of student-centered learning strategies and JTFD pedagogy, there were classroom observations using RTOP conducted at multiple times during the semester. Two people for validity and clarification conducted each classroom observation. Each faculty was observed 6 times, three pre- and three post-workshop observations. In total, 48 classroom sessions were observed and assessed with the RTOP tool. Overall, across all 8 participants an average gain of 49% was found for use of student-centered teaching strategies. For individual faculty members average gains of student-centered instruction ranged from 34% to 65%.

Further analysis of RTOP observation data was conducted to understand the fidelity of implementation and to assess which sessions of the workshop had the most positive impact. Analysis revealed that sessions 4 and 5, which focused on implementing active learning in the classroom and cooperative learning, had the strongest impact on improving RTOP scores. After

sessions 4 and 5, we found an average gain, relative to the first RTOP score, of 53% for use of active learning strategies in the classroom, with a maximum gain of 112%.

Many of the DLPs expressed that they often implemented material or strategies that they learned from the workshop immediately following the sessions, such as the think-pair-share activity. The DLPs also stated that they were constantly trying to refine and adjust classroom practices to be more student-centered, including use of muddiest points and learning objectives.

### **Communities of Practice**

Project team members met weekly during the Fall 2015 semester to review, develop, and refine workshop materials, presentations, and plan delivery of the different sessions. Through these sessions the project team members continued to grow and develop their own community of practice. In the Spring 2016 semester the workshops began with the DLPs and a new community of practice was formed, both within the cohort of the 8 DLPs and also between project members and the DLPs. Through the communities of practice all participants expanded their current understanding and knowledge of student-centered learning, including the project members and leaders. Multiple project leaders mentioned that their involvement in the JTFD project led them to make continuous changes in their own classroom instruction and has helped them to gain greater insight into engineering education practices. We also administered a Social Network survey to better understand how the DLPs worked with other faculty members to advance their teaching practices. However, the survey tool structure was not correctly implemented and the survey will be readministered.

The DLPs developed and grew their community of practice throughout the course of the workshops. They enjoyed hearing stories from other faculty members about implementing JTFD pedagogy and student-centered teaching strategies in the classroom. Ultimately, communities of practice grew in strength and are continuing to develop between project members and the DLPs.

### **Conclusions**

This paper has described the development and implementation of a large-scale faculty development program at a large southwestern university called Just-in-Time-Teaching with Two Way Formative Feedback for Multiple Disciplinary (JTFD) Programs. The project scales to seven engineering disciplines with 84 faculty using a train-the-trainer model to engage faculty in year-long apprenticeships with a semester of eight biweekly workshops followed by a semester of six biweekly mentor-supported classroom innovation implementation. The program is based upon evidence-based instructional strategies devised from the research literature and prior experience in a single disciplinary faculty development program. The project is being assessed with surveys, open-ended questions, and classroom observations. Changes in faculty beliefs are being assessed with the ATI and will be compared to fidelity of implementation of those beliefs in classroom practice as measured with classroom observations with the RTOP instrument. Faculty motivation for implementing specific innovations of contextualization of content, student-to-student interaction, and student reflection is being measure by the newly created

VECTERS instrument. Data from the first set of 8 faculty (4 disciplinary pairs) show significant gains in student-centered classroom practice. Data from the ATI and VECTERS show positive trends but the results were not statistically significant. Participation in the second year of the program has been good with 35 disciplinary cohort participants and 8 disciplinary pair leaders attending at a rate of 80%. The outlook for the future of the program is positive and we feel that the overall structure and characteristics of the program has the potential to be transportable to other institutions.

### **Acknowledgment**

The authors gratefully acknowledge support of this work by the National Science Foundation under Grant No. 1524527.

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