Faculty Embrace Collaborative Learning Techniques: Sustaining Pedagogical Change

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Introduction

Faculty development in teaching for university is often scattered and not supported in a coordinated way by science, technology, engineering, and mathematics department administrators [1], [2]. For many years Professional Learning Communities (PLC) have been a common practice in the K-12 teaching community and they provide means for teachers to learn, share, and encourage each other to develop and test new pedagogies [3]. More recently, practitioners of higher education have adopted a similar community professional development model to assist university teaching development and encourage pedagogical changes, referred to as a Faculty Learning Community (FLC) [4]. PLCS and FLCS are both examples of communities that share common interest and practice, also known as communities of practice [5]. From what we know about learning, educational institutions, faculty roles and student populations are also changing [6]. New forms of pedagogy, active learning, self-guided instruction, and group work are transforming teaching approaches, causing a shift in teaching approaches away from traditional lecture and passive students [7]. Sustainment of these teaching approaches presents challenges to faculty as incoming student populations continue to change and institutional support in faculty's pedagogical changes may falter. Levine [8] suggests, many innovations in higher education fail because they are instituted without first securing involvement and buy-in of key faculty whom they innovations more affect. Faculty's powerful voice and genuine participation often determine the success or failure of educational innovations, especially those that involve pedagogical and academic change [9]. This paper describes how two engineering faculty members implemented collaborative learning techniques through a FLC and sustained the pedagogical change by fully embracing the techniques in a variety of ways and with a variety of support structures.

Literature Review

Collaborative teaching techniques have been shown to offer tremendous benefits to student learning for several decades [10]–[12]. Benefits include: improvements in student achievement, quality of interpersonal interactions, self-esteem, student attitudes, and retention. Collaborative learning falls under an umbrella term that includes or overlaps with many terms associated with active learning in the literature, but in this paper, we use the term as defined by Barkley, Cross, and Major [13]. They described collaborative learning as any structured form of small group interactions [13], which is the definition we adopted for the implementation by FLC participants in this study. In addition to content learning and understanding gains, collaborative activities improve students' communication and social skills necessary for the global workplace.

Collaboration is a vital skill for all students, across the spectrum. For example, the challenge by Prince [12] for engineering faculty to promote collaboration in their classes is explicitly required by the accrediting agency for engineering programs [14]. Collaboration is specifically linked to the engineering curriculum via two of the 11 required student outcomes: (1) the ability to function on multidisciplinary teams and (2) the ability to communicate effectively [14]. Employers also desire graduates who can collaborate on teams; however, they report students are not well prepared in this area [15]. Engineering graduates of a large public university reported in an extensive survey the most important ABET competencies for their professional practice were teamwork, communication, data analysis and problem solving [16].

Additionally, a recent review of international literature identifying skills needed by graduate and future engineers found teamwork and communication skills to be among the top five most emphasized skills [17].

Despite the body of evidence that should inspire engineering and other STEM faculty to incorporate collaborative activities in their courses, lasting changes in teaching practice have been slow to take place [2], [18]. Fairweather [2] noted that faculty perceive curricular change will take valuable time away from research activities critical to promotion and tenure. This is not necessarily the case, as barriers to change for STEM faculty have been researched and discussed broadly, also including situational constraints. Most notably among these constraints is the fear that time taken would prevent necessary content coverage in class, student attitudes (including laziness and resistance) will impact the pedagogical change, lack of ongoing professional development, unsupportive institutional or departmental culture, and personal beliefs and expectations about teaching and learning [19]–[22]. Until recently, efforts to impact change in undergraduate STEM education focused on individual faculty innovators to test, create, and disseminate reform approaches [23]. This method of change has been challenged as unsuccessful [2], [24]. Kezar and colleagues [23] highlight the need for change agents to develop explicit change theories rather than work from implicit theories that do not show reasonable proof of success. They describe the need to create professional dialogues and support networks to implement and spread reform. Borrego and Henderson [18] identify and categorize eight change strategies supported in STEM literature, one of which is the faculty learning community.

Ralston, Tretter, and Brown [25] selected the FLC approach as the strategy to effect change among a multidisciplinary group of engineering faculty. The results from that approach included three elements of success in faculty implementation of collaborative learning techniques: (1) faculty member's philosophical position in relation to the value of collaborative learning for a particular course, (2) aligning appropriate collaborative techniques with course objectives, and (3) a fully developed pedagogy (i.e. structured follow through and integration with the course). Among the faculty participants of the FLC, almost all were successful in terms of meeting the three elements of faculty implementation of collaborative learning techniques. Some of the faculty have sustained their initial pedagogical changes by fully embracing collaborative learning as their 'new normal' teaching practice. This study explores the ways and reasons for sustaining pedagogical change and how those changes impact the student experience within their classes.

Purpose of the study

The purpose of this study was to explore ways faculty members sustain pedagogical change by embracing a pedagogical technique like collaborative learning. This study first identified common characteristics and strong indications that the faculty members had sustained their use of collaborative learning techniques. Faculty indicated various ways that they had sought out and participated in additional collaborative learning professional development to strengthen their pedagogy. Then, this study documented ways in which faculty members utilize collaborative student learning within their classes through observation of teaching practices. Finally, it highlights faculty's approaches to implementing and sustaining collaborative learning, with an emphasis on faculty utilization of technology within their teaching practice and demonstrates the effectiveness of pedagogy through various means.

Context of the study

This research was conducted within the context of an engineering school at a large urban university. The administration of the engineering school, with support of it's faculty, created a center dedicated to promoting educational excellence. That center promotes professional development opportunities for faculty, with a mission to foster outstanding teaching and learning among engineering faculty. One specific goal is to advance the use of evidence-based teaching strategies. The engineering center partnered with the university's professional development unit and a faculty member from the university's education college to encourage and engage faculty in the use of collaborative learning techniques throughout the engineering disciplines. Using the FLC framework, they offered two community of practice cohorts focused on the implementation of collaborative learning techniques in engineering courses. One cohort was conducted during a fall-calendar year in 2014-15, and another in 2015-16.

The challenge to encourage evidence-based change in teaching is not only how to educate faculty about collaborative learning techniques, but also how to support them as they attempt to implement paradigmatic changes. A paper described the approach and initial impact on the first cohort of faculty participants including support structures needed to enable faculty to implement collaborative learning techniques and the benefits participants experience from pedagogical shifts [25]. The greatest challenge, however, is to develop a community of practice capable of supporting sustainable, long-term changes in teaching pedagogy.

Research Questions

Almost two-years after the conclusion of the FLC focused on motivating faculty members to implement collaborative student learning techniques within their engineering courses, the majority of FLC participants confirmed, through semi-structured interview, their sustainment of pedagogical change; expressing some evidence of further involvement in faculty development that focused on active and collaborative learning. The faculty members that expressed fervent evidence of sustaining collaborative learning pedagogy in their classes attracted specific interest to the researchers, being that the researchers analyzing the interview data had also been the faculty's FLC facilitators. The evidence expressed by the faculty aligned with the interests of the researchers in understanding ways faculty sustain pedagogical change through an FLC experience.

This study explored ways in which faculty members sustain pedagogical change by embracing collaborative learning techniques to make the change. This research will answer the following questions:

1) What are the characteristics of a faculty member that express sustainment of a pedagogical change, after FLC support structures are removed?
2) In what ways does a faculty member embrace collaborative student learning techniques to sustain their pedagogical change?

Research Design

In the spring of 2018, nearly two-years after the conclusion of the second FLC cohort, semi-structured interviews were conducted with twelve of the fourteen FLC cohort participants. All faculty that participated in the interviews did so willingly and agreed to be interviewed, without hesitation. The faculty members identified for this study demonstrated outstandingly strong indications of pedagogical sustainment following their initial FLC experience in which

their focus was on implementing collaborative student learnings within at least one of their classes. Faculty member one (F1) of this study was a participant in the first FLC cohort and the second faculty member (F2) was a participant in the second FLC cohort.

Case study design

Qualitative data collection including semi-structured, in-depth interviews, and classroom observations were used to collect 'rich' evidence about the process each faculty member has undergone and continues to undergo to sustain the pedagogical change using collaborative learning techniques. Observation data was used only to augment and corroborate interview data, which was the main input to data analysis. The interviews were semi-structured, each completed within 45-60 minutes. All interviews followed the same structure and format (see Appendix A for interview protocol), commencing with an open discussion of teaching practices and the challenges faculty faced throughout their journey of implementing and sustaining collaborative learning techniques in their classes.

For reliability purposes, member-checking was performed following the generation of the themes and common characteristics from the semi-structured interviews. Transcript notes and corresponding themes were shared with the faculty members, to which they confirmed or shared their opinion further on themes and characteristics. All relevant data (i.e. interview transcripts, research memos, classroom observation files, etc.) were maintained in a 'case database' [27] and connections between the research questions, evidence, interpretations and conclusions were maintained throughout analysis.

This study was conducted as a multiple replication study exploring the sustainment of a pedagogical change that focused on teaching practice using collaborative learning techniques. This research design is appropriate from a systems change research perspective because of the complex and varied contexts in which pedagogical experiences and changes can elicit [28]. Understanding system change often employs cross-case synthesis which can illustrate both common themes and unique experiences [28]. For this study we wanted to study cases that demonstrated extraordinary sustainment in pedagogy that is often abandoned in teaching practice due to common challenges of time constraints or lack of institutional support.

Introducing the case studies

Case studies were conducted of two engineering faculty members, both of which expressed sustained use of collaborative learning within their courses. Additionally, both faculty members formalized their commitment to using collaborative learning techniques through their experience in a FLC cohort, focused on the implementation of collaborative learning techniques within their classes. The two faculty members are the unit-of-analysis for this study. Purposeful sampling [29] was used to identify the two faculty for this study due to the variety of creativity in their uses of collaborative learning techniques in their classes, leadership in encouraging others to engage in collaborative learning, and persistence in participation of continued faculty development in collaborative learning.

Observational classroom data was collected in three, 50-minute classes per faculty case, near the mid-point of the fall semester. The classroom observational protocol for undergraduate science [30] was used to document instructor and student moves and actions, tracked every two minutes.

Faculty member one (F1). This faculty member participated in the first cohort of the FLC focused on implementing collaborative learning techniques in engineering courses. The courses this faculty member typically teaches are the foundational mathematics courses for the engineering school, apart from some programming and advanced mathematics courses. This faculty member has a background in data security and computer science. This background is evident within the courses this faculty member teaches, with multiple technology programs and instructional software are used during class and for student study purposes.

The FLC was not this faculty member's first experience with collaborative learning techniques. In fact, this faculty member had participated in multiple active or collaborative learning professional development experiences and had facilitated another FLC focused on the integration of active learning in faculty pedagogy prior to joining the FLC for implementation of collaborative learning techniques. This faculty member is identified by colleagues as an active learning expert and can often be found counseling his peers on new techniques or approaches toward more interactive teaching and learning experience for their classes.

Faculty member two (F2). This faculty member participated in the second cohort of the FLC focused on implementing collaborative learning techniques in engineering courses. The courses this faculty member generally teaches are the foundational mathematics courses for the engineering school. With a background in aeronautical engineering, this faculty member is well versed in the content of the courses and sought the FLC due to its focus on increasing student engagement and motivation using active, collaborative student learning. The FLC was the faculty member's first professional development experience with collaborative student learning. Having explored the topic individually, this faculty member found the pedagogical changes necessary for collaborative learning implementation to be slightly overwhelming as an individual faculty. Thus, this faculty member was enthusiastic to join the FLC, when provided the opportunity.

Cross-case study findings

Explicit or implicit counts are often reflected in qualitative analysis when justifications are made. For example, we 'identify themes or patterns that happened a number of times and that consistently happen a specific way' [31]. Analysis of the case study data was conducted mainly by coding the interview data, thereby yielding counts and data points that were then analyzed further. A starting set of codes was defined ('Codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study' [31]); these codes were refined, as the analysis evolved.

Findings are presented for each of the two faculty cases, including a synthesis of classroom observation data. Following each individual case summary, the discussion is organized around the research questions and informed by a cross-case synthesis across both cases. *Authors' note: Masculine and feminine pronouns were chosen at random to anonymize participants.*

Case of F1-Technology rich, collaborative student learning

F1 is a tenured faculty member in the engineering school's foundations department, teaching various levels of calculus and linear algebra courses. When asked why he chose to participate in the first cohort of the FLC he described his focus on student learning and setting up a classroom that removes barriers or expectations of a certain "kind of learning". "It's really helpful," he describes, "in getting students to talk with each other…faculty struggle sometimes

on how to motivate that." Student interaction with each other and the material is more important to F1 than any other part of integrating collaborative learning in his courses. He uses an online note sharing software and an interactive problem-solving program during class to engage students in teamwork and working with one another to solve the problems that he designs for each class. The feedback students get during and following the problem solving 'rounds' are what F1 declares, "motivation…they're asking each other, 'what'd you get?'" This student motivation F1 identifies during class is what continues to motivate his devotion and extensive time-expenditure preparing for each class, "it's worth it [student engagement in class] …when I think of the time I spend designing questions for group work, their reactions in class make me want to keep doing it."

F1 discussed how important the peer observations (as part of the FLC experience) were to his process of becoming a collaborative learning user, "The really impactful thing was peer observations…sitting in on some other people's classes was really powerful for me…seeing other people do things, you get some ideas, but you also get a feeling for not so good [referring to what wouldn't work in his class environment]". F1 has persisted with collaborative student learning, working to redesign all his courses using the active, collaborative learning methods. F1 has also become a FLC facilitator, taking on the role as faculty developer for many engineering faculty members and helping them implementing new pedagogies until they find what works for their classroom.

In F1's reflection of his journey, so far, in continuing active and collaborative student learning in his class, he refers to the techniques as his "normal teaching". He went on to state that as students become more comfortable in his classes, they become more comfortable with the course content. This, in turn, allows him to learn more about his students as learners, strengthening his motivation to sustain in collaborative pedagogical methods.

Case of F2- Interpersonal rich collaborative learning

F2 is a non-tenured faculty member in the engineering school's foundations department, teaching various levels of calculus to first- and second-year engineering students. She accepted an invitation to join the second cohort of the FLC, and admittedly, was intimidated at first by the idea of changing her teaching approach. "I was worried about the time [referring to the amount of planning and class time implementing collaborative learning would require]" F2 indicated in her reflection of initially agreeing to the participate in the FLC. Her experience was enhanced by the integrated peer collaboration in which faculty members were partnered together and asked to observe at least one class of their faculty partner. "Every time I sat in someone else's class I found something helpful in seeing how someone else does it", she said. Peer observation proved fruitful for F2's confidence in her implementation of collaborative learning techniques as her partner confirmed that students were on task and working diligently. "[My peer observer] confirmed to me that students were working, they were even using the third person in their group as a tie-breaker of sorts." F2 describes how she wavered on how many students to put into groups, worried that too many in one group would leave some students with little or nothing to do in the problem-solving process. The FLC also offered a necessary structure of accountability for F2, "the ability to think through what kind of changes I could make [provided the time and accountability of others doing the same thing]".

F2 continued in her reflection, sharing a resounding belief of the effectiveness of collaborative student learning in the classroom. "Thinking through my goals…why I am doing things a certain way or how to better facilitate the activity…I now think through how I was doing

things and see different ways I could change…it's helped." Through this process of reflection, F2 has refined her use of collaborative student learning techniques. Originally posting problems online for student groups to work on together during 'collaborative days'; she has now gone to simple printed paper problems and provides one-copy per group. The reason, she says, was so that "they'll have to work together, at least to get the problem" and in the process they are collaboratively working through the problems and she's "there to answer questions or watch for common mistakes". The effectiveness of sustaining her pedagogical change can also be found in the engagement students exhibit during class, "students seem more interested [during collaborative learning days in class]" and "it's made it feel more alive in there [talking about the class in general]". As F2 continued comparing her previous, traditional-lecture only style of instruction to her current teaching style, it became evident to the researcher that F2 had changed her pedagogical style for good. In one of F2's final statements, this assumption was formalized, "it's [talking about collaborative learning] just part of my course now."

Classroom Observation analysis

Faculty instructors that utilize student collaborative teaching techniques have shown tremendous benefits to student learning for several decades [10]–[12]. Among these benefits are: improvements in student achievement, quality of interpersonal interactions, self-esteem, student attitudes, and retention. To characterize the interactive nature of collaborative student learning we utilized the classroom observation protocol for undergraduate STEM classroom [30] (COPUS) as a way to portray the interaction instructor and students engage in during class as well as delineate the actions students and instructor take during a typical, collaborative learning class-day.

COPUS allowed the researchers to observe F1 and F2's classes with minimal bias, as the protocol contained specific actions to be marked if observed during the class time (not allowing for extraneous observation, unless otherwise noted in a comment). The researchers used an online platform through U.C. Davis's generalized observation and reflection platform (GORP) which provided an interval timed capture, every 2-minutes, of instructor and student action(s) observed. The protocol is divided into two specific codes: 1) Students are doing, and 2) Instructor is doing.

The 'Students are doing' codes included: listening to instructor, individual problem solving, discussion among groups, working in groups on worksheet activity or other activity, as well as whole class discussion/engagement, making predictions (as a class) about an outcome, taking a test/quiz, or waiting (i.e. instructor late, or instructor occupied with administrative task). For each of these codes we were most interested in the characterization between individual actions of students (i.e. working alone or responding alone in class) compared to the events in which students were actively engaged with one another, collaboratively. Thus, we grouped the individual engagement action codes (i.e. listening, individual problem solving, waiting, and test/quiz) in one category, while the active/collaborative engagement codes (i.e. working in groups on worksheet or other group activity, answering a question in discussion with whole class, asking questions, and/or making predictions about an outcome with the whole class) were grouped into another category. The observation results, indicating the sum of three, 50-minute class observations from each of the faculty's courses are provided in Figure 1 and 2 below.

Figure 1: *F1 classroom observation data of student action codes*

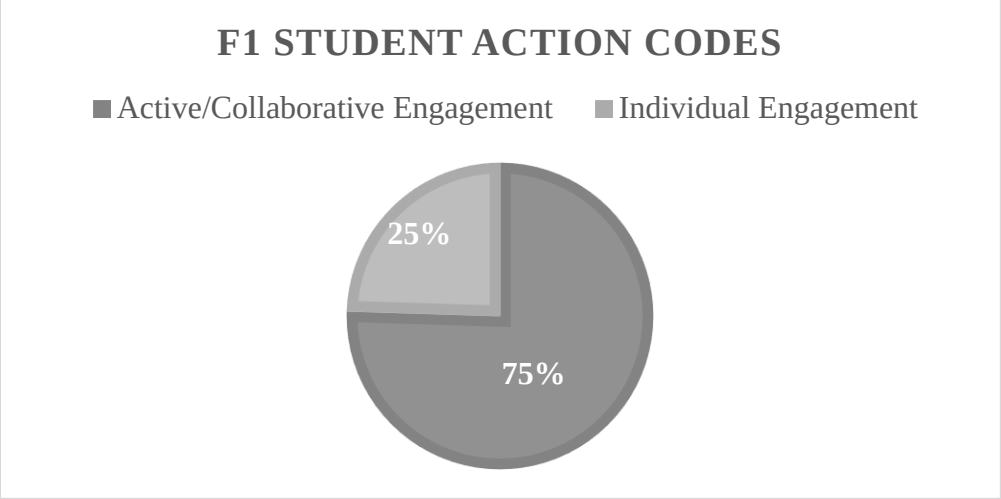
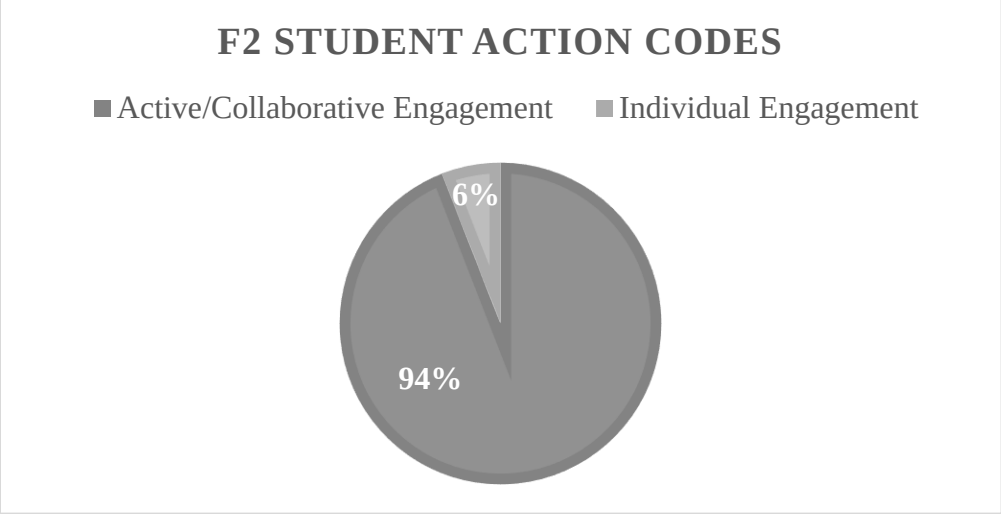


Figure 2: *F2 classroom observation data of student action codes*



From this analysis it can be observed that F1 maintains 75% of the class time in active/collaborative student engagement. Important to note with these results is that individual engagement is not meant to indicate 'lack of engagement'. Rather, these results of each of the faculty's classroom observations indicate high levels of engagement with other another, the instructor and the content of the day's lesson.

A separate code, provided by the COPUS, allowed researchers to monitor levels of engagement (as a whole-class), where high-engagement meant over 80% of the class was actively participating, medium-engagement meant between 50-79%, and low-engagement meant less than 50% of the class was actively participating. Table 1 shows the results of student engagement, based on these measures. (Note: Engagement level was indicated once for every two-minute interval, coding was not permitted to overlap for engagement level.)

Table 1: *F1 and F2 average student engagement levels*

	High-Engagement percent-average	**Medium-Engagement percent-average**	**Medium to High Engagement**
F1	74%	22%	96%
F2	82%	13%	95%

The "Instructor is doing" codes included: lecturing, real-time writing on board, feedback to question with entire class, posing a question to the students, listening/answering student questions with entire class listening, moving through the class, one-on-one discussion with student, administration (i.e. assigning homework or adjusting technology), demonstrating or displaying a predetermined display, and waiting (i.e. not interacting with students when the opportunity is available). As described in the active/collaborative learning literature, instructor actions and engagement in class should be conducive to maximizing student interaction with one another and with the instructor. Thus, we categorized the 'instructor is doing' codes into active/collaborative engagement, meaning instructor actions that elicit student activity, which included: real-time writing on board, feedback to questions, posing a question to students, listening/answering student questions, moving through the class, and one-on-one discussion with student (during collaborative learning group work). Instructor actions that elicit more individual engagement during class were coded as such, which included: lecturing, waiting, administration, and depending on the use of the demonstrating display would categorize the individual engagement. The observation results, indicating the sum of three, 50-minute class observations from each of the faculty's courses are provided in Figure 3 and 4 below.

Figure 3: *F1 classroom data of instructor action codes*

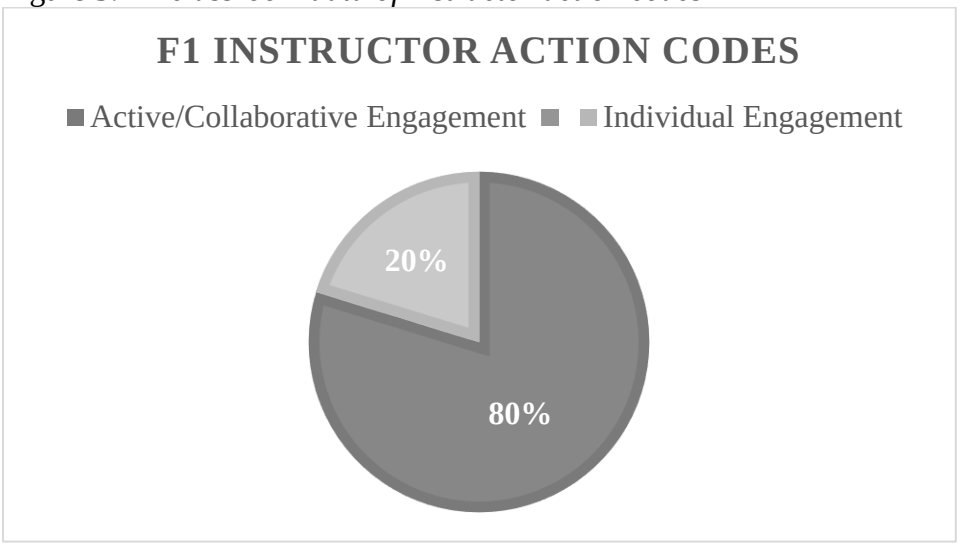
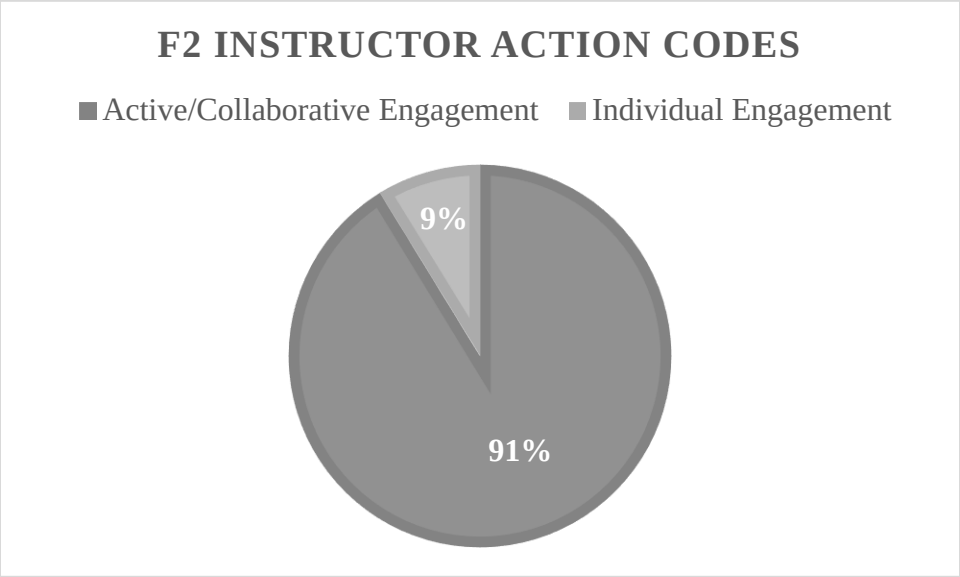


Figure 4: *F2 classroom data of instructor action codes*



Discussion

Through this research study, faculty members were able to recall successes and reflect on their original reasons to work toward pedagogical change, in the first place. Faculty characteristics, such as their beliefs in the effectiveness of collaborative learning and their continued emphasis on student needs over their own, brought out just how personal a change in pedagogy can become. Both faculty in this study were habitual in reflecting on the pedagogical practice and due to this practice of reflection, they have been able to internalize the teaching practice of collaborative learning, adapting the techniques to meet their needs as facilitators of learning.

Faculty embraced collaborative learning techniques in various ways. They exhibit leadership by encouraging colleagues to try new techniques or facilitate organized FLCs that focus on active, collaborative learning in engineering classes. Faculty also embrace collaborative learning techniques by continually discussing their pedagogy, just as F1 has become his department's collaborative learning expert. F2 continues to reinvent her question structure and ways that she structures student groups. Similar to the action and belief cycle [32], sustaining a pedagogical change requires continual and consistent effort and refinement on the part of the faculty member. When the faculty member believes in the pedagogy, their action and persistence in enacting the pedagogy will follow.

Limitations of the study

One limitation of this study was that faculty were identified prior to this study as having interest or aptitude in innovative pedagogy. The faculty accepts invitations to participation in the FLC presumable because of their interest. In addition, the faculty participants agreed that they could not have made the pedagogical changes without the dedicated time, structure, and support the FLC afforded them; not only in their initial implementation but in their sustainment of the new techniques. Faculty identified a need for a means to discuss and share with other faculty involved in similar pedagogical shifts. Any potential future faculty participants not already interested in or receptive to pedagogical change could have a very different experience; yielding

a different and may not likely to sustain or maintain the characteristics these faculty members did.

A second limitation is the interview data used in the first phase of data analysis and generation of common characteristics and themes was self-reported. The researchers were FLC facilitators and have maintained on-going relationships with these faculty, thus we are confident in their willingness to honestly share and report on their practices and continued practice of the pedagogical changes that were initialized through the FLC. Also, there was no incentive or penalty for inaccurate representations or replying to interview invitation.

Study contributions and future research

This paper reported on two faculty cases that have embraced and sustained collaborative learning pedagogy within their courses. These two cases demonstrate that faculty can make pedagogical changes somewhat easily in the short-term. However, to make long-term, sustainable change faculty need a supportive administration, community support (i.e. colleagues trying similar techniques), and a dedication to teaching and facilitating learning that benefits students. This study has implications that benefit faculty developers, faculty development facilitators, and faculty exploring ways for sustaining pedagogical change.

References

[1] M. Borrego, J. E. Froyd, and T. S. Hall, "Diffusion of engineering education innovations: A survey of awareness and adoption rates in US engineering departments," *J. Eng. Educ.*, vol. 99, no. 3, pp. 185–207, 2010.

[2] J. Fairweather, "Linking evidence and promising practices in science, technology, engineering, and mathematics (STEM) undergraduate education," *Board Sci. Educ. Natl. Res. Counc. Natl. Acad. Washington, DC*, 2008.

[3] L. Stoll, R. Bolam, A. McMahon, M. Wallace, and S. Thomas, "Professional learning communities: A review of the literature," *J. Educ. Chang.*, vol. 7, no. 4, pp. 221–258, 2006.

[4] M. Cox, "5: Faculty Learning Communities: Change Agents for Transforming Institutions into Learning Organizations," *To Improv. Acad.*, vol. 19, no. 1, pp. 69–93, 2001.

[5] J. Lave, "Situating learning in communities of practice," *Perspect. Soc. Shar. Cogn.*, 1991.

[6] L. Hainline, M. Gaines, C. L. Feather, E. Padilla, and E. Terry, "Changing students, faculty, and institutions in the twenty-first century," *Peer Rev.*, vol. 12, no. 3, p. 7, 2010.

[7] J. E. Travis, *Models for Improving College Teaching: A Faculty Resource. ASHE-ERIC Higher Education Report No. 6, 1995.* ERIC, 1995.

[8] C. D. Baldwin, R. M. Goldblum, D. K. Rassin, and H. G. Levine, "Facilitating faculty development and research through critical review of grant proposals and articles.," *Acad. Med. J. Assoc. Am. Med. Coll.*, vol. 69, no. 1, pp. 62–64, 1994.

[9] A. Furco and B. E. Moely, "Using learning communities to build faculty support for pedagogical innovation: A multi-campus study," *J. Higher Educ.*, vol. 83, no. 1, pp. 128–153, 2012.

[10] D. W. Johnson, R. T. Johnson, and K. A. Smith, *Active learning: Cooperation in the college classroom.* ERIC, 1998.

[11] L. Springer, M. E. Stanne, and S. S. Donovan, "Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis,"

Rev. Educ. Res., vol. 69, no. 1, pp. 21–51, 1999.
[12] M. Prince, "Does active learning work? A review of the research," *J. Eng. Educ.*, vol. 93, no. 3, pp. 223–231, 2004.
[13] E. F. Barkley, K. P. Cross, and C. H. Major, *Collaborative learning techniques: A handbook for college faculty*. John Wiley & Sons, 2014.
[14] ABET, "Criteria for accrediting engineering programs," 2018. [Online]. Available: http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/.
[15] S. Jaschik, "Well-prepared in their own eyes," *Insid. High. Ed*, vol. 20, 2015.
[16] H. J. Passow, "Which ABET competencies do engineering graduates find most important in their work?," *J. Eng. Educ.*, vol. 101, no. 1, pp. 95–118, 2012.
[17] M. Abdulwahed, W. Balid, M. O. Hasna, and S. Pokharel, "Skills of engineers in knowledge based economies: A comprehensive literature review, and model development," in *Teaching, Assessment and Learning for Engineering (TALE), 2013 IEEE International Conference on*, 2013, pp. 759–765.
[18] M. Borrego and C. Henderson, "Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies," *J. Eng. Educ.*, vol. 103, no. 2, pp. 220–252, 2014.
[19] C. Henderson and M. H. Dancy, "Barriers to the use of research-based instructional strategies: The influence of both individual and situational characteristics," *Phys. Rev. Spec. Top. Educ. Res.*, vol. 3, no. 2, p. 20102, 2007.
[20] J. Michael, "Faculty perceptions about barriers to active learning," *Coll. Teach.*, vol. 55, no. 2, pp. 42–47, 2007.
[21] D. W. Sunal *et al.*, "Teaching science in higher education: Faculty professional development and barriers to change," *Sch. Sci. Math.*, vol. 101, no. 5, pp. 246–257, 2001.
[22] J. J. Walczyk, L. L. Ramsey, and P. Zha, "Obstacles to instructional innovation according to college science and mathematics faculty," *J. Res. Sci. Teach.*, vol. 44, no. 1, pp. 85–106, 2007.
[23] A. Kezar, S. Gehrke, and S. Elrod, "Implicit theories of change as a barrier to change on college campuses: an examination of STEM reform," *Rev. High. Educ.*, vol. 38, no. 4, pp. 479–506, 2015.
[24] A. Kezar, "What is the best way to achieve broader reach of improved practices in higher education?," *Innov. High. Educ.*, vol. 36, no. 4, pp. 235–247, 2011.
[25] P. S. Ralston, T. R. Tretter, and M. K. Brown, "Implementing Collaborative Learning across the Engineering Curriculum," *J. Scholarsh. Teach. Learn.*, vol. 17, no. 3, pp. 89–108, 2017.
[26] R. K. Yin, "Case study research design and methods third edition," *Appl. Soc. Res. methods Ser.*, vol. 5, 2003.
[27] M. B. Miles and A. M. Huberman, "Qualitative data analysis. Beverly Hills." Ca: Sage, 1984.
[28] R. K. Yin, *Case study research and applications: Design and methods*. Sage publications, 2017.
[29] M. Q. Patton, *Qualitative research and methods: Integrating theory and practice*. London: Sage, 2015.
[30] M. K. Smith, F. H. M. Jones, S. L. Gilbert, and C. E. Wieman, "The Classroom Observation Protocol for Undergraduate STEM (COPUS): a new instrument to

characterize university STEM classroom practices," *CBE—Life Sci. Educ.*, vol. 12, no. 4, pp. 618–627, 2013.
[31] M. B. Miles and A. M. Huberman, "Drawing valid meaning from qualitative data: Toward a shared craft," *Educ. Res.*, vol. 13, no. 5, pp. 20–30, 1984.
[32] D. Navarro and K. Thornton, "Investigating the relationship between belief and action in self-directed language learning," *System*, vol. 39, no. 3, pp. 290–301, 2011.

Appendix A: Interview Questions

General Questions About Experiences with FLC and Collaborative Learning (CL) Techniques

- What do you remember about your experience in the FLC?
- Describe the most helpful aspects of the FLC.
- Were there any challenges you had with the first implementation of CL techniques?

Reflecting on CL Implementation

- What techniques learned from the FLC are you still using in your courses?
- What are some things you've changed since that first implementation?
- What problems have you encountered in implementing CL?
- Describe how you use CL in a typical class.
- Do you see yourself continuing to use CL in this or other courses?
- How do you see your use of CL changing in the future?

Students Reactions

- How have students reacted to your use of CL?

Ongoing Support and Efforts

- Do you keep in contact with other members of the FLC to discuss your courses?
    - About the use of collaborative learning in your courses?
    - Have you discussed CL with other non-FLC faculty?
- Have you sought any additional support for your courses?
    - Would you find additionally support helpful?
    - What support and communication would you like?

Impacts Outside the Classroom

- How has your experience impacted other areas of your professional life?
- Are there any additional comments you'd like to make?