Implementation of Student-Centered Teaching Methods Among
STEM Faculty

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Implementation of Student-Centered Teaching Methods Among STEM Faculty

Melissa Cavan

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

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ABSTRACT

Implementation of Student-Centered Teaching Methods Among STEM Faculty

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Master of Science

Students at the college level need good instruction and active learning has been shown to improve student retention and learning. Science, Technology, Engineering, and Math Faculty Institution (STEMFI) aims to assist faculty in implementing active learning in the classroom. This qualitative case study sought to understand faculty perspectives two years after completion of STEMFI in the areas of active learning implementation, methodology and student attitudes and impact. Data collected reported that the faculty participants still use active learning strategies in their classrooms two years after exiting the STEMFI program. The faculty also felt the need for a refresher course and felt that overall students respond well to active learning techniques. Faculty suggested a few improvements to STEMFI involving scheduling and the relevance of workshops and seminars. Overall, faculty were pleased with STEMFI and it was encouraging that faculty still use certain techniques taught during the program which can engage students as well as improve student retention and learning. With the suggestion from the faculty to have a refresher course, it would be advantageous to narrow down where the STEMFI program has been the most effective so that refresher courses could be designed as well as similar programs instituted in other departments, colleges, or at other universities. Although this professional learning program is focused on STEM faculty, it would be important for a university to consider how the main tenants of this program could also be used with faculty in other disciplines. This could provide needed and important knowledge for faculty in humanities, arts, education, and business to make changes in their classroom practice as well as additional avenues of research.

Keywords: active learning, case study, pedagogy, professional development, student-centered learning
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They say that it takes a village to raise a child, but I believe it takes a village to write a thesis. I have been blessed with so many great people in my life who have pushed me to be where I am now. First and foremost, I would not have made it this far without my committee chair, Heather Leary. She pushed me in just the right way to help me get things done without stretching me beyond my limits. I am truly grateful for the many hours she has spent helping me through this process. I also appreciate the knowledge of my committee members, Charles Graham and Royce Kimmons, with their incredible insights and encouraging words. The entire Instructional Psychology and Technology Department is incredible with great teachers and wonderful students who I call my friends.

My family has been my foundation. My siblings are amazing and have always been there for me. My mom and dad instilled the importance of education from an early age with my mom encouraging me to earn good grades in school to my dad nudging me toward college and cheering me on the whole way. My children and step-children have shown great patience as I put homework before housework and game-time. Lastly, my husband has been the cornerstone of my foundation with encouraging words when I needed them and simple acts of kindness when things got discouraging.
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DESCRIPTION OF THESIS STRUCTURE

This thesis, *Implementation of Student-Centered Teaching Methods Among STEM Faculty*, is written in a journal ready format. The initial pages of the thesis reflect requirements for submission to the university. The main body of the thesis is the research article, *Implementation of Student-Centered Teaching Methods Among STEM Faculty*. This article is formatted for journal submission; I provide the references used for this article at the end of that section. An extended literature review, which synthesizes research findings related to student-centered and active learning in the classroom as well as the importance of implementation of these methods and the effect that mentoring has on retention and implementation of student-centered methods is in Appendix A. Due to word length restrictions in the journal-ready article, portions of the extended literature are not reused there. Appendix B provides the Institutional Review Board approval letter by the BYU Human Research Protection program. Appendix C and D include the instruments used in the research.

There are two journals of interest. The main one of interest is *Professional Development in Education*. This journal has completed 47 volumes of publications, the citescore is 2.8, and one of their main focuses involves professional development and approaches to professional learning (International Professional Development Association, 2019). Another journal is *New Directions for Teaching and Learning* which has published 164 issues. Their goal is to look at improving techniques for college teaching by using knowledge from seasoned instructors and looking at the latest research findings (Wiley Online Library, 2019).
Implementation of Student-Centered Teaching Methods Among STEM Faculty

People who attend graduate school to obtain a doctoral degree (PhD, EdD) often devote four to seven years to the program. The average time for most PhD graduates is 5.8 years (Kowarski, 2019), and in that time they take classes, do numerous hours of research, write journal-ready papers and sometimes teach courses. In essence, they become an expert in their field of study and learn in depth about a specific topic. A doctoral degree can potentially be used to find profitable employment, and one of those options is to become a professor/faculty at a university. In fact, at most colleges a masters’ degree is required to simply teach a college level class, even as an adjunct (“How to become a college professor,” 2010). In most cases, universities require a PhD for a tenure-track position. Requiring this caliber of degree indicates that people want highly educated instructors at the college level. Yet, in all the time they spent obtaining a Masters’ or PhD the people pursuing this degree were usually never required to take a class on pedagogy or teaching methods.

In contrast, for someone to become an elementary, middle, or high school teacher they are required to take several classes on teaching methods, classroom management, and curriculum writing. They often have to complete a student teaching program and earn a teaching certificate before even being considered for a full-time teaching position (McGee, 2020). So, why is it that to teach below the college level these requirements need to be met, but at the college level they do not? College students are older and often more mature than high school students, which may imply less need for strict curriculum standards or disciplinary action from the instructor. Yet with that maturity comes more focus and attentiveness to the instructor, meaning it would be beneficial if they knew effective teaching methods. It is anticipated that the instructor would be
held to a higher level of expectations because they would need to present the material well, but also have a firm background of the content to be able to answer in-depth questions.

College students need good teachers just as much as high school and middle school students. This becomes apparent when looking at student retention rates. The Chronicle of Higher Education (2019) recorded the retention rates of freshmen from fall 2015 through fall 2016 in the United States, with the following highs and lows after one year of college: University of Wisconsin Madison 95.4%, University of Georgia 95.2%, and Ohio State University 94.3%, Shaw University 47.9%, Lincoln University 46.7% and Stillman College in Alabama at 39.7%. Despite the reasons for these retention rates, it does seem that those rates could potentially be higher if freshmen students had outstanding, interactive instructors. Of course, there could be other reasons for these retention rates, such as financial situations, family crisis or circumstances, poor preparation in secondary schools, stricter entrance requirements, or college courses being too rigorous. But challenges such as these only make it all the more important for students to have active and engaged learning experiences in college to improve, at least in one area, the likelihood that they will not drop out during their first year.

Incorporating student-centered and active learning in the classroom has reportedly helped with retention rates. It has been studied and often shown that students retain information better and are less likely to drop out if the classes are engaging and entertaining (Prince, 2004). Stephen Bowen describes the importance of engaged learning saying, “engagement is increasingly cited as a distinguishing characteristic of the best learning in American higher education today” (2005, p. 4).

When it comes to instructor pedagogical background, it would appear that most colleges recognize these flaws in the system and have developed programs to aid instructors in their
pedagogical endeavors. Programs such as the Center for Teaching and Learning (Brigham Young University, 2019) or the Office of Teaching and Learning (Utah Valley University, 2019) as well as the Engagement & Faculty Development program (University of New Hampshire, 2021) and the Berkeley Center for Teaching & Learning (University of California at Berkeley, 2021) are dedicated to helping professors become more effective instructors. There are even professional journals supporting communities to help staff that work in these centers, such as *The Journal on Centers for Teaching and Learning*. These programs are a great resource for teachers and offer assistance when an instructor has a question or needs a few suggestions, but for an instructor to really utilize improved pedagogy and implement it in the classroom the teaching methods need to become something of habit and something that they practice repeatedly.

Applying pedagogy in Science, Technology, Engineering, and Mathematics (STEM) courses takes time and assistance to do effectively and has discipline specific needs.

The goal of this research was to understand faculty implementation of active learning in the classroom who have participated in the Science Technology Engineering Math Faculty Institute (STEMFI) professional development program, to make comparisons and identify trends among faculty mentoring, and to explore which implementation strategies have helped faculty and which ones have not, as well as any common barriers that faculty encounter when trying to implement change and active learning in the classroom.

**Literature Review**

Many people would agree that the top priority of a university should be the education and knowledge retention of its students. Faculty and instructors are an integral part of conveying information to students and they should know and use good teaching techniques. The key to getting instructors excited about teaching techniques is to give them the tools and knowledge of
which techniques work and get them to teach those methods to others. Active learning in the classroom has been shown to improve learning (Armbruster, 2009). This literature review provides a brief introduction about how active learning is defined, the importance of active learning, and the effectiveness of implementing the pedagogical skill of active learning in the classroom.

**Active Learning**

Lecture-based teaching is typically a passive activity for students and includes the instructor lecturing while the students listen and make an effort to memorize what is being taught. Active learning (often referred to as student-centered learning), on the other hand, “involves students in doing things and thinking about the things they are doing” (Bonwell & Eison, 1991, p. 2). Bonwell and Eison list the following as characteristics of active learning:

1. Students are involved in more than passive listening
2. Students are engaged in activities (e.g., reading, discussing, writing)
3. There is less emphasis placed on information transmission and greater emphasis placed on developing student skills
4. There is greater emphasis placed on the exploration of attitudes and values
5. Student motivation is increased (especially for adult learners)
6. Students can receive immediate feedback from their instructor
7. Students are involved in higher order thinking (analysis, synthesis, evaluation) (p. 2).

More recently, active learning was defined as “any instructional method that engages students in the learning process” (Prince, 2004, p. 223). Active learning includes different types of teaching approaches such as collaborative, cooperative, and problem-based learning.
(Cuseo, 1992; Johnson et al., 1998; Millis & Cottell, 1998; Prince, 2004; Smith & MacGregor, 1992) and is often contrasted with lecture-based instruction as a student-centered activity where the learners are not passively taking in information but engaged in the learning process. The techniques and activities associated with active learning are usually introduced and implemented in the classroom with some activities for learners to do outside of class time, and the core elements are student activity (e.g., small group work) and engagement (Prince, 2004).

**Importance of Active Learning**

Active learning purports that if students are more engaged during class, they are more likely to perform better and retain more of the information. This is especially true in the STEM field in which the classes need engagement and interaction so that students can think critically and harness problem-solving abilities essential for their careers. Researchers and educators believe “[I]t is important for our youth to be equipped with the knowledge and skills to solve challenging problems, gather and evaluate information, and interpret data” (Stanberry & Payne, 2018, p. 147). Active learning provides the structure and opportunity for this and “when students are taught to think deeply, they have opportunities to become the future innovators, educators, researchers, and leaders in our country and the world” (Stanberry & Payne, 2018, p. 147).

One barrier in the STEM field is keeping students engaged with content because it is easy to lose interest in a topic if it seems challenging or tedious (Stanberry & Payne, 2018). This often puts pressure on the instructor to create an engaging learning environment in an attempt to pique student interest in the content and the discipline overall. Stanberry and Payne (2018) stated “It is a known fact that sometimes the course content in STEM classes is challenging, but the learning environment can have a major impact on student interest and motivation” (p. 148). She also mentioned that students will often leave the STEM field before realizing their potential, but
when active learning techniques are used there is an increased interest in STEM classes due to increased critical thinking skills and retention of information. Creating an active learning environment does mean additional work for the instructor, and ongoing professional development can provide the means to assist instructors with using active learning in their classrooms. The potential results of incorporating active learning in the classroom are higher test scores, increased retention as well as increased student involvement and interest.

Evidence for Effectiveness of Active Learning

Active and engaged learning provides the means to create an effective learning environment for student learning and retention when implemented in the classroom (Deslauriers et al., 2019). Research on active learning indicates positive outcomes for students. Knight and Wood (2005) conducted a study over four semesters on the effect of introducing active learning in the classroom. One semester utilized a traditional lecture method and the second semester incorporated active learning. They ran the same study again over two semesters to compare the results with the first two. The results included higher test scores, higher overall grades, and better skills for solving conceptual problems during semesters where active learning was incorporated. Student responses to the active learning method were mixed with most students reporting that it helped their learning and a few stating that they did not like the group work. Haruta and Stevenson (1999) reported qualitative and quantitative evidence of the effectiveness of implementing active teaching methods at the collegiate level. Haruta and Stevenson had faculty attend a professional development course, which included workshops, seminars, and networking. Faculty interviews and student surveys were analyzed. The results were high marks in favor of program implementation, and higher student enrollment in the classes with faculty who had been
through the program. There was also an increase in student retention rates (Haruta & Stevenson, 1999).

A report written by Singer et al. (2012) pertains to discipline-based research and discusses the effectiveness of interactive teaching. Lecture-based classes are still the go-to method for many STEM professors, but even introducing a little more interaction can increase student learning and retention. Singer et al. (2012) outlines several methods professors use to introduce active learning into the classroom and the different ways they have been beneficial to students. One example of active learning is implementing just-in-time processes, in which the students submit homework problems and questions before class, and the instructor adapts their lecture based on the students’ responses. This small change in pedagogy resulted in an increase in study habits, and students were better prepared for class. Singer et al. mentions lecture demonstrations in which the instructor has a physical demonstration and the students walk through the steps of making a prediction, discussing the prediction with their peers, observing the outcome of the demonstration, and comparing the outcome with their prediction. Singer et al. showed that when students collaborated with a group they performed better on tests compared to students who did not work in groups.

Using meta-analysis, Freeman (2014) compared test scores, grades, and failure rates to understand if active learning had any effect in those areas. Freeman found that examination scores increased by six percent with active learning, and in contrast the students in the lecture-based class were one and a half times more likely to fail out of the class. A six percent increase may not seem like a very high number but this meta-analysis combined 225 studies, quite a large number of studies. When measuring active learning they included any type of active learning, so using occasional problem-solving, worksheets, or tutorials during class time all counted as being
Implementing Active Learning

The research on active learning reports that active learning is an effective method for improving student retention and increasing test scores, yet some instructors have a hard time implementing active learning in the classroom. Some of the most common barriers faculty experience when implementing active learning are time constraints, instructional challenges such as class size and content coverage, and student preparedness and resistance (Shadle et al., 2017). It is important to address these barriers properly to have effective implementation of active learning. Shadle et al. (2017) stated “the opposite of dissatisfaction is not satisfaction and vice versa; rather, barriers and drivers are separate factors that need to be accounted for individually” (p. 2). She found the most common driver for faculty change in teaching was collaboration with colleagues, especially those who had already made pedagogical changes as well as resources offered by the university. One way to foster this change in teaching is through professional development programs, which have positive outcomes on teacher development for classroom pedagogy (Lynch et al., 2019).

In some cases the help that faculty need is in professional development programs, and these programs have taken some different approaches when it comes to understanding the best way to guide instructors. One method is understanding their beliefs about teaching (epistemological beliefs) to help improve professional development approaches (Marouchou, 2011). Another way is by understanding some of the faculty barriers and using active learning...
methods with the instructors (Birman et al., 2000). After faculty attend a professional
development program, the next question might be whether the faculty implement what they
learned during the program. There are many articles pertaining to the effectiveness of active
learning (Henderson et al., 2008; Knight & Wood, 2005; Prince, 2004; Sawada, 2002; Singer et
al., 2012), yet it is harder to find research on instructor implementation of active learning
methods. Simonsen (2019) came close by doing a study on the implementation of positive
classroom behavior support (PCBS) practices. Simonsen addresses the importance of educators
to use proper classroom management, and active learning practices, but then she addresses that
implementation rates are lower than desired.

After reviewing the literature on active learning, the underlying theme present is that
students benefit when faculty implement good teaching methods, which often involves active
learning in the classroom. How that is defined can be different, but moving away from lecture-
based teaching practices to those that engage the students in the learning process, encourage
them to think critically, and expect them to take an active role in their own learning are all
important features of active learning techniques. For faculty to learn what active learning is and
how to implement it in their classrooms, professional development programs are essential to
guide them as well as support them during implementation. It is important to know whether
faculty are using what they learn in a professional development program and whether they are
applying that knowledge in their own classroom.

Methods

This qualitative case study (Stake, 1995) examined faculty implementation of student-
centered teaching methods during and after participation in a National Science Foundation (NSF)
funded program at Brigham Young University called Science Technology Engineering and Math
Faculty Institute (STEMFI). The STEMFI program aims to help higher education STEM instructors learn about and implement student-centered methods of instruction. This study was guided by the following research questions:

1. What student-centered classroom activities are being implemented by faculty who have participated in at least one year of the STEMFI program?
2. What are the differences in teaching methods between faculty who continue through the STEMFI program as mentors and those that exit after the first year?
3. What professional learning techniques help faculty better implement student centered activities in the classroom?

Context

This research builds from a larger NSF-funded program at Brigham Young University called the Science Technology Engineering Math Faculty Institute (STEMFI) professional development program. STEMFI began in 2018 with its first cohort of STEM faculty and is now working with its third cohort. The purpose of STEMFI is to build faculty capacity on student-centered teaching strategies through training and practice. This professional development program includes mentors for every faculty member that participates. The STEMFI program designed and delivered a structured program as well as collected research data with each cohort covering various aspects of the program.

Participants

Participants in this case study included the 15 STEM faculty from the first cohort of the STEMFI program, including: three faculty from biology, two from mechanical engineering, two from exercise science, three from chemistry, two from physics, two from public health, and one from nutrition. The range of years teaching at BYU among these 15 faculty was from two to 20,
with the majority of them averaging around 18 years of teaching experience. After completion of the first year, faculty from the first cohort were given the opportunity to mentor faculty participating in the second cohort. Eight faculty from the first cohort continued as mentors the second year.

To narrow the selection of faculty to interview for this study, the following steps were taken. First, data collected during the first year of the STEMFI project by the STEMFI researchers, including classroom observations using the Classroom Observation Protocol Undergraduate STEM (Smith et al., 2013) and faculty background information, were reviewed to understand which faculty exhibited changes or no changes in their implementation of active learning. Then, all 15 faculty who participated in the first cohort of STEMFI were invited to take a short online survey asking about their past and current active learning activities in their classrooms. The purpose of reviewing this data was to identify faculty who had made changes in their classroom activities to include more active learning as well as those who did not make changes. Using this data, three faculty were selected and invited to be interviewed.

**Data Collection**

Data for this study included a semi-structured hour long interview with three faculty selected from the first cohort of STEMFI. The interviewer asked questions centered on experiences in the STEMFI program and how faculty were implementing some of the concepts taught during the program in their classes.

**Data Analysis**

To answer the research questions, data from the faculty interviews were analyzed using thematic network analysis (Attride-Stirling, 2001) and vignettes of the three faculty were created using STEMFI Cohort Data and interview data. For the thematic network analysis, basic themes
were determined and grouped into organizing themes with global themes emerging at the end. Figure 1 is a representation of basic, organizing, and a global theme. During the observations and interviews it was noted whether faculty were using traditional lecture methods or if they were using student-centered methods, it was also noted which student-centered methods were being used for those in which the active learning was being implemented. The content was analyzed for trends in teaching methods between instructors who volunteered to be mentors and those who did not, to see if being a mentor had more of an effect on implementation of active learning in the classroom. Content was analyzed for variations among instructors in different departments or with varying years of experience. These results were compared to methods the faculty were using before entering the program to see whether or not there was a shift. Themes were determined pertaining to barriers faculty often encountered when implementing active learning, as well as which methods worked for implementation and which ones did not.

**Figure 1**

*Example of Attride-Stirling (2001) Thematic Analysis*
Trustworthiness

To establish trustworthiness, peer briefing and member checks were conducted. Two researchers reviewed the data and discussed any interpretations made pertaining to the interviews, observations, and survey data. Basic, organizational, and global themes generated from the data were initially created by one researcher. A second researcher reviewed the organizational and global themes, asking questions and making suggestions for groupings and theme names. Once the data from the interviews was analyzed it was reviewed by the faculty interviewed and checked for correct interpretation.

Limitations

In the middle of the research process all university classes were shifted to an online and remote setting. Instructors expressed decreased ability to do certain active/engaged learning activities while holding classes remotely.

The disruption of moving to remote instruction due to the COVID-19 pandemic decreased potential communication and interaction with faculty (e.g., lack of access to them in their offices or personal phones). Thus, the number of potential participants to interview was lower than expected. Another limitation was that all the faculty selected to interview were male faculty due to the two female faculty involved in cohort one declined to participate in the study.

Results

The results are presented as three faculty vignettes (faculty names have been changed to protect identity) followed by a thematic analysis. The vignettes describe the instructors’ beliefs and attitudes toward teaching and instructional methods generally, their experiences in the STEMFI program, and their experiences implementing active learning. The thematic analysis
presents the main themes related to implementing active learning, their observation of student responses to active learning in the classroom, and impressions of STEMFI.

**Faculty Vignette: Liam**

Liam has been teaching at an accredited university for about four years. His Classroom Observation Protocol for Undergraduate STEM (COPUS) data from his time in the STEMFI program and his survey results from this research indicate an increase in active learning in the classroom after participation in the STEMFI program. In his classes Liam utilized group activities more than other active learning techniques, both in large classes where *think, pair, share* is used but instead of having every group share what they discussed groups are picked at random, but also breaking students into groups of about 30 and having a TA guiding each group. Liam expressed frustration with the same set of students being the ones to speak up in class and lead the small groups, while the quiet students continue to be quiet and not engage in group activities. Liam attempted to get around this problem by assigning roles to students during group work to get interaction from everyone. Some students responded negatively to this technique of “role playing” and felt the desire to just be themselves. Liam found value in explaining to his students the definition of student-centered/active learning and why he is implementing it in class. Some students respond positively to his explanations, especially in his upper-level classes, but others, like in the lower-level classes, just want to know the information and what is going to be on the tests.

Liam volunteered to be a mentor after completing the first year of STEMFI. His reason for mentoring was to stay fresh and to have a second look through the material. Liam’s data shows that he has been able to continue with several active learning techniques taught in the
STEMFI program indicating that being a mentor could help solidify some of those concepts. Liam also expressed pleasure in being able to help someone else through the process.

Liam relayed a few techniques of his own that he has found to be helpful in implementing active learning. One suggestion was looking to the literature surrounding student-centered teaching and then involving the students in that process. Liam will present a question to the students, which they will often bring up, such as posting PowerPoints for them before class. Liam was not sure what the literature said on the matter and so he gave an assignment to his students to research it and present the findings to him. Liam also suggested reading blogs for ideas on incorporating active learning and turning to resources available at universities that are designed to give assistance with teaching methods to faculty members.

Regarding the STEMFI program, Liam found the seminar helpful and indicated that during the workshops it was beneficial to implement real life situations and see how they played out. Liam also found the handouts helpful especially when they tied into the workshop and gave clear break downs. Liam felt that the peer observations were not helpful. He found them beneficial in viewing the ways other faculty teach and appreciating their approach to teaching, but he did not feel that he picked up new techniques, possibly due to the faculty being in a different department and teaching a different subject. One suggestion that Liam had for improving the STEMFI program was to create a refresher course.

Faculty Vignette: Greg

Greg has been teaching at an accredited university for about 12 years. He has had highs and lows when it comes to incorporating active learning. At times when he has tried something new his student ratings have gone down. Greg is still willing to try new techniques and continues to incorporate active learning in his classes. Greg reported using active learning in the classroom
about the same amount before and after the program (neutral change). During the interview Greg stated that he loved the STEMFI program and that he is still using techniques taught in the program despite the fact that he did not sign on to be a mentor during the second year. He also stated that he has forgotten some things from when he was in the program.

Greg often does group activities in class including the *think, pair, share* method, which he indicated gets used almost every class period. Greg has implemented a Process Oriented Guided Inquiry Learning (POGIL) method where he gives students a worksheet and reviews some of the material at the beginning, then he lets the students work on the next portion of the worksheet in groups, lastly he brings them back together and discusses a few concepts at the end. He indicated a positive response from students when using this method. Greg also uses quizzes to keep the students’ attention during class and will sometimes give the students a quiz that they can work on as a group or one that he will give the answers to during class in order to keep the students engaged and listening. As far as implementation of material learned from STEMFI, Greg picked around two or three methods to concentrate on and become comfortable with. He did recognize that he did not implement everything.

Greg did not participate in the mentor program for STEMFI because he thought he would be gone the following year. He did not end up leaving during that time and indicated regret for not participating in the mentor program. He mentioned being willing to do the mentor program in the future, even though it has been a few years since he attended the program. Greg enjoyed STEMFI and expressed a willingness to help in the coming years.

Greg indicated that when implementing student-centered activities, it is a struggle to get through all the required material and that the more student-centered activities he implemented the less material he was able to get through. He also stated that it did not bother him because he
would prefer the students understand a few things rather than not understanding many things. Greg trusts the students and puts some of the responsibility back on them to review material that they did not have time to cover on their own.

Some advice that Greg gave concerning teaching was that student evaluations drive what faculty do, especially faculty that are working toward tenure. However, student ratings are not always the best indication of student learning. Greg has noticed that in some cases, faculty who are great entertainers and have an easier class often bring in high student evaluations, and yet faculty that are less entertaining and strict end up with low evaluations. Greg feels that student-centered activities are a great way to get students to pay attention, retain the information and still maintain good evaluations. It can be risky implementing them the first time though, and there is a chance that ratings could go down.

In terms of the STEMFI program, Greg is very supportive and felt that the time allotted for faculty to work on their material as part of the workshop was very beneficial. It allowed him to prepare his lectures for the coming semester and not stress when the class drew near. Greg did express frustration with the way the recordings were handled. He did have someone come to his class to record for later observation, but he was not given any advanced notice that they were coming to do the recording. He also had an issue with scheduling conflicts between himself and his mentor. They taught at the same time and so it was hard for his mentor to observe his teaching and give advice.

**Faculty Vignette: James**

James has been teaching at an accredited university for about 11 years. His data indicates an increase in active learning in the classroom after participation in the STEMFI program. James did become a mentor the second year claiming it was because they asked him to, but he seemed
to find meaning and value in being a mentor and expressed full support for the program. James indicated usefulness in STEMFI and that he has implemented a portion of what he learned during the program. He feels that he has successfully implemented what was taught, even though it was not all of it. James feels that faculty should not try to implement all of what they learn in the program. They need to be open to new ideas and able to recognize which methods will work for their specific classes. James took his lecture material and converted it to active learning exercises. He has the students start with an easy exercise to be done on their own, with himself and his TA walking around the classroom to offer help. Afterwards he will discuss the concepts and give a demonstration of the proper method. Then, he will make the next assignment harder and continue to increase the rigor of the assignments. James did express frustration with having time to cover all the material and “close the loop” as he phrased it. He does feel that this process is an improvement.

James uses daily quizzes to emphasize key concepts, utilizing “make it stick” ideas. He refuses to use student response system quizzes in his class and feels that technology should not get in the way of teaching. He switched from giving one midterm and a project to giving four midterms. The rationale was to put students into panic mode. James stated “the idea being that students seem like they do all their learning when they’re in panic mode about an exam. And so I’m like, Okay, well, we’ll just make it be tons of exams. So you’ll have to learn all the time.” James does not find value in assigning students to groups, but he will encourage students to discuss concepts with their neighbor and will sometimes ask a group to share something they discussed. James wants to try a flipped classroom approach in the future. He tried it in the past with mixed results but feels that with the extra ideas discussed during STEMFI he might have better success implementing a flipped class. His biggest struggle with a flipped class is the loss
of control. The responsibility shifts to the students, and if the students do not do their part before coming to class then time is wasted explaining concepts to those who did not prepare properly.

James volunteered to be a mentor after completion of the first year in the program. He stated that he did it because they asked him to, but he also said he enjoyed his experience in STEMFI, thought it was useful and wanted to support the program.

James mentioned a few things that have helped him with implementing student-centered teaching methods. One is having peer interaction. In his department there is a group of six or seven individuals that get together and discuss literature pertaining to teaching in their field of study. He mentioned getting ideas for some of his classes simply by talking with peers. Another suggestion was to talk with experts in the field of teaching to get ideas from them. James does also feel that getting students’ attention during class is key, that is why he does not do clicker questions, but he will have students raise their hand when he asks a question. He feels that it snaps the students into paying attention if they have to physically raise their hand.

James enjoyed the STEMFI program overall, but he struggled with the theoretical aspects. He preferred to just be told how to make his class better. He did find the initial cohort meeting valuable but found less value in the subsequent cohort meetings. He was not against them but did not feel that he changed aspects of his class by going to the subsequent meetings. James appreciated that the program is centered on teaching in the STEM fields so that more concepts apply to his subject, but he did still see significant variability in class types and therefore methods or strategies of teaching.

**Thematic Analysis**

From the three faculty who participated in an interview four global themes emerged: (a) classroom tools and techniques, (b) STEMFI impressions, (c) instructor thoughts, and (d) student
responses to classroom changes. Under the global theme *classroom tools and techniques*, the following three organizing themes arose: (a) classroom tools, (b) techniques used in class: individual, and (c) techniques used in class: group work (see Figure 2). All three organizing themes were important for the faculty in balancing various activities in the classroom. Individual work was discussed more by faculty, but they noted that group work was just as valuable.

Classroom tools describe online tools such as learning management systems, quizzes (e.g., Kahoot!, Poll Everywhere), or video recordings created and employed by the faculty for students to engage with before or during class. Some hardware, such as Clickers, were mentioned by the faculty. The organizing theme of *techniques used in class: group work* refers to the active learning activities that have students working together in small or large groups discussing and exploring the classroom content. These techniques include activities such as *think, pair, share*, neighbor work, and large classroom discussions. The organizing theme *techniques used in class: individual* describes techniques to engage, motivate, and pique interest for each individual student with the class content. Based on the number of basic themes, there is a higher trend toward individual work with group work not discussed as much by the faculty. The classroom tools the faculty reported they used were typical tools currently used in classrooms, such as video lectures with quizzes and learning management systems.
The second global theme of STEMFI impressions contains the following four organizing themes: (a) STEMFI: suggestions, (b) STEMFI: not useful, (c) STEMFI: useful, and (d) mentoring (see Figure 3). The organizing theme of STEMFI: suggestions refers to a small number of recommendations made by the faculty for modifications to the STEMFI program. The main suggestion was to develop a refresher course. The organizing theme of mentoring refers to
if they continued as a mentor and why or why not. The STEMFI: not useful theme describes various elements that the faculty did not find as much value in or did not like as part of the STEMFI program. In contrast, the STEMFI: useful theme describes the elements of the STEMFI program the faculty did value and found beneficial for their practice. Although the themes of mentoring and suggestions were discussed, the faculty continually referenced the level of usefulness of STEMFI.

In addition, the faculty had more positive things to say about the program, with a few comments pertaining to what was not useful, yet the main suggestion given was to provide a refresher course, indicating that they found the program helpful and would be willing to attend refresher courses. During the program the most common theme that they found useful were the workshops and having time to work on their classes.
Figure 3

*Thematic Network for the Global Theme STEMFI Impressions With Accompanying Organizing Themes and a Sample of Basic Themes*

- **STEMFI: Useful**
  - Seminar useful
  - Workshop: implementing real-life situations
  - Workshop: positive, handouts helpful
  - Supporter of STEMFI
  - Groups are useful
  - Workshop: time to prepare material

- **STEMFI: Not Useful**
  - Cohort meetings
  - Peer observations
  - Theoretical not as useful
  - Different technologies were cool but distracting

- **STEMFI: Suggestions**
  - Need a refresher
  - Forgotten some things from being in STEMFI

- **Mentoring**
  - Help others in the program
  - Mentored to keep concepts fresh
  - They asked me to
  - Did not mentor—thought was going to leave
  - Gives refresher

**Key:**
- [Global Theme](#)
- [Organizing Themes](#)
- [Basic Themes](#)
For the global theme *instructor thoughts*, the following five organizing themes arose: (a) professional development, (b) teacher attitude, (c) degree of implementation, (d) teacher suggestions for teaching, and (e) barriers for implementation (see Figure 4). The global theme of instructor thoughts was largely due to instructors having a lot to say, the emphasis of their thoughts seemed to revolve around professional development and what they are currently doing to continue implementing active learning. The theme of *professional development* refers to what the faculty have done and currently do for professional learning, such as attending book clubs and seminars, talking with colleagues, or engaging with centers for teaching and learning.

*Teacher attitude* identifies the faculty’s outlook on pedagogy for classroom implementation, awareness of professional needs, and using student-centered activities. This theme addresses instructor thoughts and feelings about active learning in the classroom including how their attitudes have changed after implementing active learning and feelings about continuing the process. The theme *degree of implementation* identifies the extent faculty have used the techniques learned in the STEMFI program in their own classroom and how much they feel they have utilized active learning strategies. The organizing theme of *teacher suggestions for teaching* refers to ideas faculty would share with colleagues on best teaching practices using active learning techniques. This also included advice for keeping students engaged in the classroom.

*Barriers for implementation* relates to any obstacles that might hinder faculty from implementing student-centered activities such as time and resources needed for implementation.
Finally, the global theme student responses to classroom changes had two organizing themes: (a) student response negative, and (b) student response positive (see Figure 5). These
organizing themes describe what the faculty observed from their students after implementing an active learning technique and how the students responded to it. There are an even number of themes for positive and negative, this does not necessarily mean that the student responses are evenly split, it just means that the instructors mentioned the positive and negative student responses equally.

**Figure 5**

*Thematic Network for the Global Theme Student Responses to Classroom Change With Accompanying Organizing Themes and a Sample of Basic Themes*
There is an even distribution of basic themes under the global themes of *classroom tools and techniques* (29 themes), *STEMFI impressions* (27 themes), and *instructor thoughts* (30 themes). With *student responses to classroom changes* having the least number of basic themes (16 themes). Of the organizing themes *techniques used in class-individual* had the largest number of basic themes (15 themes). The organizing theme of *STEMFI suggestions* only had three basic themes, the main theme being to offer a refresher course. Even though the global theme of *student responses to classroom changes* had the least amount of basic themes, the themes presented were evenly split between the two organizing themes: *student response negative* (eight themes) and *student response positive* (eight themes). Overall, results indicate a positive experience and outlook with the STEMFI program for the faculty participants as they continued to implement active learning techniques in their classrooms.

**Discussion**

This case study of faculty at Brigham Young University who participated in the first cohort of the STEMFI professional development program indicates that faculty have continued to implement student-centered active learning activities in their classrooms. The most common activities used were *think, pair, share*, small group discussions with reporting to the class, and in-class quizzes. Why these are the most used is not as clear but could result from the positive difference the faculty observe with their students when using these activities to their engagement and knowledge of the content or perhaps these student-centered activities align with the individual faculty members’ personal teaching philosophies, or these activities were ones frequently modeled and discussed in the professional development workshop they attended.

In implementing active learning, the faculty noted a trend toward more individual work than group work activities. It is interesting that there was not a more balanced use of individual
and group activities, which might be due to more generalized descriptions of group work, whereas there are many ways to describe different individual active teaching methods. The difference in group and individual work is noteworthy here because the STEMFI workshop highlights and models group work balanced with individual activities.

The instructors are using a variety of tools in the classroom to incorporate active learning and feel that what they use is working effectively. The faculty noted that there were some tools they did not like and would not use, most likely due to the difficulties associated with implementing them. From the faculty observations of students, there were some techniques the students seemed to not like, indicating that not all active learning activities will be embraced by the students in a positive way. That might result from students’ reactions to the first time ever using these techniques or a previous poor experience with them. It is heartening that faculty reported positive responses from students related to active learning, shown through their engagement in the classroom.

The faculty expressed that the STEMFI program was useful, with the main suggestion being a refresher course. Although, the thoughts from the STEMFI: not useful theme indicate other improvements that could be made as well as elements of the program that were not useful for them individually they most likely felt those elements might be useful for other disciplines. Teasing out what is useful overall versus what is useful for an individual faculty member and their discipline is not easy to do and is something all professional learning programs struggle with. Interestingly, the main barrier for implementing active learning was the individual faculty’s fear of negative student evaluations which could affect promotion and tenure. During the interview with James he mentioned relief that he was already tenured saying, “I'm glad I'm
tenured because I wouldn't be doing this if I wasn't. Because there's no room for experimentation creativity or failure before [tenure]."

The faculty indicated talking with colleagues to get ideas and keep them motivated to improve their teaching methods, which is one way to deal with not having an additional refresher course. As the faculty implemented active learning in their classrooms, they did not try to do it all. They were selective on the activities they implemented based on what they believed might be useful for their content and students. So, the faculty were all wise enough to know not to try it all or they had been coached well to know not to try it all. The faculty in the STEMFI program clearly take their teaching responsibilities seriously and show they want to make improvements to their craft.

These results do not report big differences between faculty who continued as mentors and those who did not. This could be due to the size of the cases, as two of the three faculty continued as mentors and one did not. A larger sample size might produce differences among the faculty who were or were not mentors and their implementation activities. Research has shown that peer coaching or mentoring can be an effective method for improving teaching and increasing student academic achievement (Kraft et al., 2018). All of the faculty had positive things to say about the STEMFI program itself and how the workshop helped them gain more knowledge and practice with student-centered, active learning techniques. Not all of them agreed that the follow-up activities with their peers were helpful, but that follow-up activities are a good idea. This aligns with current sentiment in professional learning activities in which one-stop workshops are not effective, but that professional learning needs time for practice and reporting of that practice with peers.
Conclusions

Research has shown that active learning is beneficial to student learning (Deslauriers et al., 2019) which means it is up to the faculty to initiate active learning in the classroom. Programs like STEMFI aim to teach faculty active learning techniques so they have the skills and confidence to implement active learning. This qualitative case study aimed to explore faculty involved in the first cohort of the STEMFI program and to gauge their implementation of concepts and teaching methods taught during the program as well as what the faculty are doing to continue using active learning in the classroom. There was a trend among the selected faculty that they are still implementing active learning in the classroom and that there is a desire to continue to improve.

With the suggestion from the faculty to have a refresher course, it would be advantageous to narrow down where the STEMFI program has been the most effective so that refresher courses could be designed as well as similar programs instituted in other departments, colleges, or at other universities. Instructors should constantly be striving to find new ways to improve their teaching and enhance the student experience as well as the retention of knowledge. The STEMFI program offers an avenue for instructors to incorporate active learning in the classroom which is beneficial for the students and thereby beneficial to the university as a whole.

Although this professional learning program is focused on STEM faculty, it would be important for a university to consider how the main tenants of this program could also be used with faculty in other disciplines. This could provide needed and important knowledge for faculty in humanities, arts, education, and business to make changes in their classroom practice as well as additional avenues of research. Thus, faculty and students in all disciplines would be introduced to active learning and the benefits of using it in educational settings.
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APPENDIX A

Extended Literature Review

In this literature review I first give a brief introduction about education reform in STEM education. Next I define active learning and like terms, and I discuss the importance of active learning and the effectiveness of implementing the pedagogical skill of active learning in the classroom. After which I mention methods used for measuring the frequency of active learning in the classroom.

Introduction

In the late 20th century, political and education leaders in the United States pushed for reform in K12 and higher education classrooms in response to lower student achievement (McCombs, 2003). The worry was the country and its students were falling behind other countries. This push initiated changes to be more learner-centered in individual classrooms and expanded the teaching techniques (e.g., collaborative learning, service learning) used by instructors to promote more engagement from students in their learning, also known as active learning (Lazerson et al., 2000). Learning communities were formed for faculty and instructors to improve their practice and there was a slight drop in lecture-based teaching in favor of learner-centered activities. Even though some individual instructors were teaching differently, there was little visible impact on overall teaching practices and deeper reform (Kennedy, 2005).

There has been a renewed push in recent years to re-evaluate how STEM classes are taught, both in K12 and higher education, and how active learning can be used for greater student success (Bybee, 2010; Fendos, 2017; Kezar & Gehrke, 2017). In K12 classrooms, there has been an increased focus to teach students how to do science properly, think creatively, and make STEM courses more inclusive. STEM courses in higher education though continue to rely
primarily on lecture-based instruction (Stains et al., 2018; Wheeler & Bach, 2020) even though research indicates that active and engaged learning increases student knowledge and retention (Michael, 2006). Since many faculty in higher education have limited teaching qualifications, as most are trained as researchers, they typically teach as they were taught using lecture-based instruction and focus on the transfer of content knowledge (Chadha, 2020; Fendos, 2017). To increase faculty’s teaching capacity, many institutions provide professional learning opportunities for faculty that go beyond content knowledge to include innovative pedagogical approaches, such as active learning.

Professional learning is a complex process and for STEM faculty in higher education, it is important to address beliefs and attitudes as well as introduce innovative pedagogical activities (Avalos, 2011; Chadha, 2020). A lack of awareness on the part of faculty about other ways of teaching, beyond didactic lecture-based techniques, is something professional learning programs address. But often faculty are skeptical and find it hard to break away from what they have always done. This can often yield disappointing implementation results from the professional learning activities (Bergh et al., 2015). As teaching is an important part of higher education, especially for student learning and success, breaking down barriers and increasing knowledge and actions around innovative teaching practices is important.

**Active Learning**

Lecture-based teaching is typically a passive activity for students and includes the instructor lecturing while the students listen and make an effort to memorize what is being taught. Active learning (often referred to as student-centered learning), on the other hand, “involves students in doing things and thinking about the things they are doing” (Bonwell & Eison, 1991, p. 2). Bonwell and Eison lists the following as characteristics of active learning:
1. Students are involved in more than passive listening
2. Students are engaged in activities (e.g., reading, discussing, writing)
3. There is less emphasis placed on information transmission and greater emphasis placed on developing student skills
4. There is greater emphasis placed on the exploration of attitudes and values
5. Student motivation is increased (especially for adult learners)
6. Students can receive immediate feedback from their instructor
7. Students are involved in higher order thinking (analysis, synthesis, evaluation) (1991, p. 2).

More recently, active learning was defined as “any instructional method that engages students in the learning process” (Prince, 2004, p. 223). Active learning includes different types of teaching approaches such as collaborative, cooperative, and problem-based learning (Cuseo, 1992; Johnson et al., 1998; Millis & Cottell, 1998; Prince, 2004; Smith & MacGregor, 1992) and is often contrasted with lecture-based instruction as a student-centered activity where the learners are not passively taking in information but engaged in the learning process. The techniques and activities associated with active learning are usually introduced and implemented in the classroom with some activities for learners to do outside of class time, and the core elements are student activity (e.g., small group work) and engagement (Prince, 2004).

**Collaborative Learning**

Prince (2004) defines collaborative learning as “any instructional method in which students work together in small groups toward a common goal” (p. 223) and Laal et al. (2013) defines it as “students working together to solve a problem, complete a task or create a product” (p. 4057). The core element of collaborative learning is student interaction instead of learning
individually (Prince, 2004). It is not meant to be a study group where students simply talk with each other and does not involve students working individually with a select few helping those who fall behind. Collaborative learning is a joint activity designed to involve each member of the group in a collective task or problem to solve in which each student has a role to play helping complete the task or solve the problem (Laal & Laal, 2011). This approach shifts the role of the instructor from an expert transmitter of information to an expert designer of experiments as well as a mentor and coach (Laal et al., 2013). Collaborative learning is “an umbrella term for a variety of educational approaches involving joint intellectual effort by students, or students and teachers together” (Smith & MacGregor, 1992, p. 1). Collaborative learning involves students’ exploration of course materials, but instructor lecturing does not need to disappear, it can live alongside active learning approaches (Smith & MacGregor, 1992).

**Cooperative Learning**

Cooperative learning is similar to collaborative learning, but is defined as “a structured form of group work where students pursue common goals while being assessed individually” (Prince, 2004, p. 223). The core element for cooperative learning is group or cooperative incentives which could be achieved using individual accountability, in-person promotive interaction, mutual interdependence, practice of interpersonal skills, and self-assessment of team functioning. One difference between collaborative and cooperative is in cooperative learning the instructor still maintains control of the learning environment by designing the activities, forming the groups and monitoring student interactions (Li, 2013), in collaborative learning the instructor acts as a coach or facilitator (Laal et al., 2013) to assist and guide but not design and implement the activity.
The jigsaw method is one form of cooperative learning where students are placed in groups of four to six. Each student in the group is assigned a portion of the material and becomes an “expert” in that area. The groups break apart and collaborate with students assigned to the same portion of material that they are to discuss and review the material. Next, the students are placed back in their groups and each student teaches the rest of the group their assigned topic (Tarhan & Sesen, 2012). There is definite overlap between collaborative and cooperative learning, but the outcome for both is higher student achievement, improved social skills and an increased capacity to work together productively (Tarhan & Sesen, 2012).

**Problem-Based Learning**

Problem-based learning (PBL) is an instructional approach “that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem” (Savery, 2006, p. 9). In PBL, problems are introduced at the beginning of an instructional cycle and as a group learners are expected to define their own learning objectives and goals to solve the problem (Prince, 2004; Wood, 2003). Subsequently learners do independent, self-directed study before returning to the group to discuss and refine their acquired knowledge” (Wood, 2003, p. 1). This shifts responsibility to the students and requires them to take responsibility for learning the content needed for the whole group to succeed (Hmelo-Silver & Barrows, 2008). Some key characteristics when implementing PBL in the classroom include: learners in small groups and collaboration among the learners, using ill-structured (real-world) problems that integrate a wide range of disciplines, learners taking on the responsibility for their own learning, application of information from all self-directed learning returned to the small groups with the intent to reanalyze and come to a resolution on the problem, self and peer assessment, and a closing analysis of the activities and what was learned (Savery,
2006). As PBL has expanded from medical education into K12 education, corporate learning, and higher education, how it is used and defined has been changed and adapted for the different contexts. Prince (2004) emphasizes that these various definitions can be used but that authors need to be precise in their explanations of PBL in specific contexts so that it is clear to the reader in which context the author is using the terms.

**Importance of Active Learning**

Active learning purports that if students are more engaged during class they are more likely to perform better and retain more of the information. This is especially true in the STEM field in which the classes need engagement and interaction so that students can think critically and harness problem solving abilities essential for their careers. Researchers and educators believe “[I]t is important for our youth to be equipped with the knowledge and skills to solve challenging problems, gather and evaluate information, and interpret data” (Stanberry & Payne, 2018, p. 147). Active learning provides the structure and opportunity for this and “when students are taught to think deeply, they have opportunities to become the future innovators, educators, researchers, and leaders in our country and the world” (Stanberry & Payne, 2018, p. 147).

One barrier in the STEM field is keeping students engaged with content because it is easy to lose interest in a topic if it seems challenging or tedious (Stanberry & Payne, 2018). This often puts pressure on the instructor to create an engaging learning environment in an attempt to pique student interest in the content and the discipline overall. Stanberry and Payne (2018) stated “It is a known fact that sometimes the course content in STEM classes is challenging, but the learning environment can have a major impact on student interest and motivation” (p. 148). She also mentioned that students will leave the STEM field before realizing their potential, but when
active learning techniques are used there is an increased interest in STEM classes due to increased critical thinking skills and retention of information.

Creating an active learning environment does mean additional work for the instructor, and ongoing professional development can provide the means to assist instructors with using active learning in their classrooms. The potential results of incorporating active learning in the classroom are higher test scores, increased retention as well as increased student involvement and interest.

**Evidence for Effectiveness of Active Learning**

Active and engaged learning provides the means to create an effective learning environment for student learning and retention when implemented in the classroom (Deslauriers et al., 2019). Research on active learning indicates positive outcomes for students. Knight and Wood (2005) conducted a study over four semesters on the effect of introducing active learning in the classroom. One semester utilized a traditional lecture method and the second semester incorporated active learning. They ran the same study again over two semesters to compare the results with the first two. The results included higher test scores, higher overall grades and better skills for solving conceptual problems during semesters where active learning was incorporated. Student responses to the active learning method were mixed with most students reporting that it helped their learning and a few stating that they did not like the group work.

Haruta and Stevenson (1999) reported qualitative and quantitative evidence of the effectiveness of implementing active teaching methods at the collegiate level. Haruta and Stevenson had faculty attend a professional development course, which included workshops, seminars, and networking. Faculty interviews and student surveys were analyzed. The results were high marks in favor of program implementation, and higher student enrollment in the
classes with faculty who had been through the program. There was also an increase in student retention rates (Haruta & Stevenson, 1999).

A report written by Singer and colleagues (2012) pertains to discipline-based research, and discusses the effectiveness of interactive teaching. Lecture-based classes are still the go-to method for a lot of STEM professors, but even introducing a little more interaction can increase student learning and retention.

Singer and colleagues (2012) outline several methods professors use to introduce active learning into the classroom and the different ways they have been beneficial to the students. For example, just-in-time processes, in which the students submit homework problems and questions before class, and the instructor adapts their lecture based on the students’ responses. This small change in pedagogy resulted in an increase in the students’ study habits and they were better prepared for class.

Singer et al. (2012) mentions lecture demonstrations in which the instructor has a physical demonstration and the students walk through the steps of making a prediction, discussing the prediction with their peers, observing the outcome of the demonstration, and comparing the outcome with their prediction. Singer et al. showed that when students collaborated with a group they performed better on tests compared to students who did not work in groups.

Using meta-analysis, Freeman (2014) compared test scores, grades, and failure rates to understand if active learning had any effect in those areas. Freeman found that examination scores increased by six percent with active learning, and in contrast the students in the lecture-based class were one and a half times more likely to fail out of the class. A six percent increase may not seem like a very high number but this meta-analysis combined 225 studies, quite a large
number of studies. When measuring active learning they included any type of active learning, so using occasional problem-solving, worksheets or tutorials during class time all counted as being active learning. If this study were refined to include more involved active learning that number might be different. Freeman also found that class size had an effect on the active learning process, with smaller classes having higher test scores when active learning was implemented. However, class size was not a factor in regards to failure rates.

**Tools for Observing Active Learning**

There are those who criticize the methods used to measure the effectiveness of active learning in the classroom, often because the measurement methods and their validity are not reported and the methods used do not consider a variety of learning outcomes (Hartikainen et al., 2019; Prince, 2004). Sawada (2002) addressed this issue of measuring change in the classroom and developed a system called The Reformed Teaching Observation Protocol (RTOP). This protocol used the literature on reformed classrooms and established a model of what reformed teaching should be, taking into consideration national standards. It allowed observers to draw a quantitative conclusion on the degree of reformation in the classroom. This tool presented an observation method to demonstrate improved student retention and learning in the reformed classes. This protocol was also found to work across many different disciplines, but especially in the fields of math and science.

Sawada (2002) observed 16 instructors from three different disciplines (mathematics, physical science and physics) and calculated the mean RTOP to use as the RTOP score for that class. Then, the normalized gain score is calculated, which is the post-test minus the pre-test and this normalized score is compared to the RTOP. This type of protocol could be very beneficial for measuring the effectiveness of faculty implementation of student-centered learning methods.
Common observation methods could be used, but by using the RTOP method in addition to common field observation methods this could appease both the quantitative and qualitative researcher. It could also give more merit and validity to any claims of implementation.

Another method of measuring implementation in the classroom is the Classroom Observation Protocol for Undergraduate STEM (COPUS). This protocol is meant to document classroom behavior in two minute intervals without the observer making judgments about teaching quality. COPUS uses 25 codes from two categories. The codes describe what the students are doing as well as what the instructor is doing during class time. Observers can be easily trained on how to use the protocol, and the results are typically visualized in the form of a pie chart (Smith et al., 2013).

The Active-Learning Inventory Tool was developed to provide a valid and reliable active learning inventory tool (Van Amburgh et al., 2007). Using existing and published literature, the tool was developed and tested with education researchers with the intent of measuring active learning in large classrooms. Since active learning is a good teaching strategy to engage students in the learning process as well as build critical thinking skills (Brown & Freeman, 2000; Gokhale, 1995), which is an important skill in STEM fields, having a good tool to use to provide necessary evidence of the success of an often dismissed teaching technique was important. This tool focused on active learning techniques as well as how to create change in faculty teaching practices. This was the first active learning tool to use qualitative and quantitative data to understand active learning in a classroom.

**Implementing Active Learning**

The research on active learning reports that active learning is an effective method for improving student retention and increasing test scores, yet some instructors have a hard time
implementing active learning in the classroom. Some of the most common barriers faculty experience when implementing active learning are time constraints, instructional challenges such as class size and content coverage, and student preparedness and resistance (Shadle et al., 2017). It is important to address these barriers properly to have effective implementation of active learning. Susan Shadle and colleagues stated, “the opposite of dissatisfaction is not satisfaction and vice versa; rather, barriers and drivers are separate factors that need to be accounted for individually” (2017, p. 2). She found the most common driver for faculty change in teaching was collaboration with colleagues, especially those who had already made pedagogical changes as well as resources offered by the university. One way to foster this change in teaching is through professional development programs, which have positive outcomes on teacher development for classroom pedagogy (Lynch et al., 2019).

Another potential reason faculty may be resistant to change is comfort and not straying far from what is known. It is likely that they were taught using lecture-based methods and that method of teaching is familiar and comfortable. In regard to exposure to more than lecture-based teaching techniques “many professors have not experienced the critical thinking approach as part of their own education; their models have been lecturers and dispersers of information. They teach what they know” (Haas, 1998, p. 63). Also, for some faculty research is their main focus and teaching may come second which makes the time constraint more of an issue (Chadha, 2020; Fendos, 2017).

In some cases the help that faculty need is in professional development programs, and these programs have taken some different approaches when it comes to understanding the best way to guide instructors. One method is understanding their beliefs about teaching (epistemological beliefs) to help improve professional development approaches (Marouchou,
Another way is by understanding some of the faculty barriers and using active learning methods with the instructors (Birman et al., 2000).

After faculty attend a professional development program, the next question might be whether the faculty implement what they learned during the program. There are many articles pertaining to the effectiveness of active learning (Henderson et al., 2008; Knight & Wood, 2005; Prince, 2004; Sawada, 2002; Singer et al., 2012), yet it is harder to find research on instructor implementation of active learning methods. Simonsen (2019) came close by doing a study on the implementation of positive classroom behavior support (PCBS) practices. Simonsen addresses the importance of educators to use proper classroom management, and active learning practices, but then she addresses that implementation rates are lower than desired. She encourages educators and administrators to look at the data presented and provides a way to use the data to build a support system for students and educators when it comes to implementing good teaching skills. The article does not specifically say what level of education is being studied, but it does imply K12 education due to the mention of administrators and school leadership teams.

Simonsen’s approach to higher education encourages the need for a support system when implementing different teaching methods. She mentions professional development systems which include training, modeling, coaching, and feedback, but that these professional development systems fall short when it comes to supporting the educators with implementation of these concepts in the classroom (2019). Simonsen also provided a model to illustrate how faculty can evaluate their implementation of PCBS practices and the support systems needed to assist them. This model could be applied to the collegiate level by replacing school leadership teams with colleagues or specific departments within the college. The concepts of monitoring and implementing certain teaching methods can easily be incorporated into this diagram.
Conclusion

After reviewing the literature on active learning, the underlying theme present is that students benefit when faculty implement good teaching methods, which often involves active learning in the classroom. How that is defined can be different, but moving away from lecture-based teaching practices to those that engage the students in the learning process, encourage them to think critically, and expect them to take an active role in their own learning are all important features of active learning techniques. For faculty to learn what active learning is and how to implement it in their classrooms, professional development programs are essential to guide them as well as support them during implementation. It is important to know whether faculty are using what they learn in a professional development program and whether they are applying that knowledge in their own classroom.

Future research should study implementation rates to determine how often faculty implement and how to support them and encourage them to use/continue to use active learning techniques. Understanding the trends in faculty attitudes and behaviors, as well as common barriers that faculty encounter are important to understand so support is designed well. Being aware of the activities that helped support faculty implementation of active learning would be important to know too. Having a full picture of faculty attitudes, beliefs, barriers, knowledge, current classroom practices, and the support they need will help in the development of strong professional learning programs that will be effective in teaching faculty about active learning so they can effectively implement it in their classroom.
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APPENDIX B

Institutional Review Board Approval Letter

Memorandum

To: Jamie Jensen
Department: BYU - LSCI - Biology
From: Sandee Ams, MPA, HRPP Manager
Wayne Larsen, MAcc, IRB Administrator
Bob Riddle, PhD, IRB Chair

Date: March 30, 2020
IRB#: IRB2020-003
Title: The STEM Faculty Institute (STEMFI) to Promote Faculty Change

Brigham Young University’s IRB has approved the research study referenced in the subject heading as expedited level. Category 6: Collection of data from voice, video, digital, or image recordings made for research purposes, and Category 7: Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. These categories do not require an annual continuing review. Each year near the anniversary of the approval date, you will receive an email reminding you of your obligations as a researcher. The email will also request the status of the study. You will receive this email each year until you close the study.

The IRB may re-evaluate its continuing review decision for this decision depending on the type of change(s) proposed in an amendment (e.g., protocol change the increases subject risk), or as an outcome of the IRB’s review of adverse events or problems.

The study is approved as of 03/30/2020. Please reference your assigned IRB identification number in any correspondence with the IRB.

Continued approval is conditional upon your compliance with the following requirements:

1. A copy of the approved informed consent statements and associated recruiting documents (if applicable) can be accessed in IRB. No other consent statements should be used. Each research subject must be provided with a copy or a way to access the consent statements.
2. Any modifications to the approved protocol must be submitted, reviewed, and approved by the IRB before modifications are incorporated in the study.
3. All recruiting tools must be submitted and approved by the IRB prior to use.
4. In addition, serious adverse events must be reported to the IRB immediately, with a written report by the PI within 24 hours of the PI becoming aware of the event. Serious adverse events are: (1) death of a research participant, or (2) serious injury to a research participant.
5. All other non-serious unanticipated problems should be reported to the IRB within 2 weeks of the first awareness of the problem by the PI. Prompt reporting is important, as unanticipated problems often require some modification of study procedures, protocols, and/or informed consent processes. Such modifications require the review and approval of the IRB.

Instructions to access approved documents, submit modifications, report complaints and adverse events can be found on the IRB website under IRIS guidance: http://orca.byu.edu/irb/IRIS/story_html.html.
APPENDIX C

Faculty Survey

Please complete the following survey based on your experience in the STEMFI program and your implementation of concepts learned during the program.

Rank of a scale of 1-5 with 1 being strongly disagree and 5 being strongly agree

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student centered/active learning is a productive way to teach students.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Rank on a scale of 1-5 with 1 being dissatisfied and 5 being very satisfied

<table>
<thead>
<tr>
<th>Question</th>
<th>Dissatisfied</th>
<th>Somewhat Satisfied</th>
<th>Neutral</th>
<th>Satisfied</th>
<th>Very Satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>How satisfied were you with the STEMFI workshop?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>How satisfied were you with the STEMFI focus group?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>How satisfied were you with the mentor program?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>How satisfied were you with your progress throughout the program?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Overall how satisfied were you with the STEMFI program?</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Please rank the following based on your teaching methods BEFORE attending STEMFI with 1 being never and 5 being always.
Please rank the following based on your teaching methods AFTER attending STEMFI with 1 being never and 5 being always.

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>Sometimes</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughout the semester how often did you lecture during class?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>How often did you use group discussions in the classroom?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>How often did you give quizzes during class time?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>How often did you do group activities in the classroom?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>How often did you use clicker questions during class time?</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
After attending STEMFI did you volunteer to become a mentor? Yes  No

What did you find most useful about the STEMFI program which helped you better implement student centered activities in the classroom?

___________________________________________________________________________________
___________________________________________________________________________________
___________________________________________________________________________________

What advice would you give for improvement of the STEMFI program in the future?
___________________________________________________________________________________
___________________________________________________________________________________
___________________________________________________________________________________
APPENDIX D

Faculty Interview Questions

The faculty will be recorded and so the interviewer will make the faculty member aware of the fact that the interview will be recorded.

1. You chose to be a mentor this year, why did you decide to continue on as a mentor? 
Or….You chose not to be a mentor after the first year, why did you decide not to be a mentor?

2. Do you feel like you have successfully implemented the methods taught during the STEMFI program? Why or why not (elaborate)?

   a. If you have implemented changes in your teaching methods, how do you feel it has been received by students?

   b. (Based on survey answers) You said that you use ____________ (e.g., clicker questions, group discussions) tell me about how you plan/facilitate ____________(same as above).

3. What aspects of the STEMFI program did you find most useful/helpful to implement active learning in the classroom (prompt with: workshops, mentoring, focus groups)?

4. (Take input from survey and ask to elaborate) You said that STEMFI could improve ____________ could you elaborate on that?

   a. What would’ve helped you to better implement change?

5. Outside of STEMFI what professional learning techniques have you found to be helpful in making changes in the classroom or in implementing active learning?

6. Do you have any other comments?