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Flipping STEM Classrooms Collaboratively Across Campuses in California

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Flipping Classrooms Collaboratively Across Campuses

In 2015, San José State University (SJSU), in partnership with California State University-Los Angeles (CSULA) and California State Polytechnic University, Pomona (CPP), was awarded a prestigious First in the World (FiTW) grant, funded by the Department of Education. This grant was focused in bringing the flipped classroom pedagogy to seven gateway STEM courses over three years, through a collaborative partnership across the three campuses. Recent research on flipped learning has suggested that its active use in STEM courses facilitates student engagement and promotes student success (Hake, 1998; Deslauriers, Schelew, & Wieman, 2011). To this end, our approach was to implement this model into high-failure gateway courses across the campuses to evaluate the impact on student learning and achievement. In addition to using this active pedagogy, we also included a multi-disciplinary, cross-campus faculty learning community (FLC) that serves as an active learning model for our faculty as well as provides training and support during development and implementation of the flipped classroom. This approach is based on the Community of Inquiry Framework (CoI), which states an educational experience is a blend of social presence (establishing strong relationships), cognitive presence (moving beyond understanding to exploration, integration, and application), and teaching presence (a combination of environment and directed facilitation components).

Flipped Learning and Faculty Learning Communities

The flipped classroom is a student-centered learning environment and uses active learning instructional strategies that reverse the traditional didactic learning environment by delivering content outside of the classroom. That is, students review course materials (e.g., lecture, readings) before coming to class. Class time is then used for problem-solving activities, homework, class peer interactions and group work, and hands-on interactive activities.

Recent research has documented this pedagogical trend across disciplines and also noted that this approach is one of the most effective instructional models in terms of student engagement and performance (Hao, 2016). Several studies have shown that this instructional strategy leads to higher levels of motivation and engagement, as well as greater student autonomy and performance (Flumerfelt & Green, 2013; Smit, Brabander, & Martens, 2014). Some of the key reasons that this technique is believed to be effective are that students have more control over their learning, they are using more 'cognitive' strategies for learning, and they are given more personalized, individualized assistance and instructor time. Despite the increasing number of research studies that support the use of flipped learning for motivation and performance, it is critical to note that some studies have found that student response to and readiness for flipped learning is not universally positive (e.g. Wilson, 2013). That is, some students struggle with this approach to learning and may have difficulties with the greater self-discipline and accountability required with this approach.

STEM educators have traditionally relied on the lecture-based, teacher-centered model of learning. Although the number of faculty using active-learning, student-centered models is increasing, the number of STEM faculty using active learning is still not equivalent to faculty use in other disciplines (Borrego, Froyd, & Hall, 2010; Walczyk & Ramsey, 2003). In their 2010-2011 report, the Higher Education Research Institute (HERI) surveyed faculty teaching undergraduate courses and found that 69.7% of male STEM faculty and 50.4% of female STEM faculty were extensively using traditional lecture in their courses (Hurtado, Eagen, Pryor, Whang, & Tran, 2011). In comparison, only 43.7% of male non-STEM faculty and 27.8% of female non-STEM faculty used traditional lecture as their main instructional strategy. Overall, STEM faculty have been slower to adopt more active learning pedagogies than faculty in other disciplines.

However, similar to other disciplines, it is important to note that integrating active learning into STEM classes is linked to higher levels of student learning and improved achievement (Hake, 1998). Freemana et al. (2014) found in their recent meta-analysis of 158 active learning studies that students in traditional lecture STEM courses were significantly more likely to fail than those students who were in active learning STEM courses; students in these STEM courses made greater gains in their learning. Other studies within the STEM disciplines have also found performance gains and greater student success in flipped classrooms (e.g., Fautch, 2015, Eichler & Peeples, 2016).

A critical priority at many STEM institutions is to increase the number of under-represented minority (URM) groups and women in STEM fields and to close the achievement gap that these students face (Lewis, Menzies, Najera, & Page, 2009; National Academy of Sciences, 2007). Active learning approaches are a promising direction to apply within STEM disciplines as there is evidence that these approaches are critical for these high-need, at-risk students (Weddle-West & Bingham, 2010). That is, students in active learning courses may have increased academic confidence, may have greater motivation to persist in their academic pathways, and may be more motivated to persevere to graduation (Adair, Reyes, Anderson-Rowland, & Kouris, 2001). There is also evidence that the flipped setting specifically works to improve student engagement and student retention (Stone, 2012). This may be particularly true for at-risk students. At-risk students (including those who are URM) often become overwhelmed with their STEM coursework and are challenged by the complex nature of these STEM courses (Householder & Hailey, 2012). Preliminary research from minority-serving institutions shows a dramatic drop in failure rates after the implementation of the flipped learning approach (Peters, 2005) and that this approach also works to increase retention and test performance (Kim, Patrick, Srivastava, & Law, 2014).

Some of the biggest challenges to implementing the flipped approach to learning are limited faculty time and opportunity to participate in reflective practice. Implementing a flipped approach requires a change in and re-envisioning of the traditional classroom; faculty are challenged not only in their approaches to teaching, but also in the time it takes to deliver a flipped classroom (i.e., developing out-of-class content and substantive in-class activities). Developing sustainable Faculty Learning Communities (FLCs) may be one effective approach to addressing these challenges. In higher education, FLCs have recently received attention as a way to increase faculty support and increase collaboration and cohesiveness within disciplines (Ward & Selvester, 2012). FLCs can be defined as a small group of faculty (and professional staff) who engage in a sustained curricular program focused on enhancing teaching and learning and that provide faculty with the opportunity to engage in active collaborations with one another through dynamic community building (Shulman, Cox, & Richlin, 2004). FLCs can provide faculty across disciplines with the opportunity to share instructional strategies, materials, best practices and engage in intellectual discussions that help empower faculty to be agents of change in their courses, departments, and universities and even in mentoring other faculty.

Research on FLCs has shown a positive impact on faculty and course delivery/design (Horvitz & Beach, 2011). Faculty who are part of an active FLC have showed self-efficacy gains and have effectively improved their teaching strategies. FLCs also have an impact on student outcomes. Cox (2004) noted specific gains in student's learning and achievement when their faculty were part of active FLCs. Although FLCs have strong benefits, there are barriers and challenges to the success of these collaborative groups. For example, Hubball and Albon (2007) point out that scheduling difficulties, discipline difficulties, lack of rewards and faculty culture all can be detrimental to FLC collaborations and reflective practice.

First in the World Grant (FiTW)

The work funded by the FiTW grant is focused on implementation of the flipped classroom approach in 7 gateway STEM courses (i.e., courses with high failure rates, tend to prevent forward progress towards degree completion, and tend to pose challenges for at-risk students) at three Minority Serving Institutions (SJSU, CSULA, and CPP) over a four-year period. These institutions are all MSIs, but have very different demographics within that designation, as shown in Table 1. Courses involved in the primary grant activities include Calculus I, Circuits, Physics (I and II), Discrete Math, Statics, and Computer Science.

	SJSU		**CSULA**		**CPP**	
	HC	**%Total**	**HC**	**%Total**	**HC**	**%Total**
AmInd	4	0.1%	16	.4%	17	0.2%
Black	111	2.6%	149	3.4%	275	2.9%
Asian	1,715	40.3%	828	18.6%	2,428	25.9%
Pac Isl	33	0.1%	7	.1%	21	0.2%
Hispanic	837	19.6%	2,526	56.9%	3,261	34.8%
White	901	21.1%	374	8.4%	2,136	22.8%
Foreign	309	7.3%	297	6.7%	444	4.7%
Other	350	8.2%	246	5.5%	802	8.5%
Total	**4,260**		**4,443**		**9,149**	

Table 1. Demographic information for SJSU, CSULA, and CPP shows that all three universities have large minority populations, but that the demographics of those minority populations vary significantly.

In the first year of the grant, all core faculty were trained to use the flipped approach to engage diverse learners. In addition, workshops were provided to expose faculty to the CoI Framework and discuss best practices in teaching URM students, being agents of change at their respective universities, and specific methods for developing engaging activities inside and outside of the classroom. Faculty were purposively linked across the three campuses in their same disciplines to share development and review of active learning materials and to engage in discipline-specific intellectual discussion of curriculum and best models of instruction. In the first year, core faculty in Calculus I and Physics I were developing materials (although some were already actively engaged in flipping prior to the grant), and then began the implementation.

An innovative part of this grant program is the Faculty Learning Communities (as well as the Faculty Learning Community Coordinators). These FLCs provide a collaborative arena in which faculty colleagues across disciplines and within disciplines have the opportunity share their materials, participate in reflective practice, and be empowered to be change agents in their departments and institutions. They also inspire cross-campus collaboration, which encourages development of materials that are more universal and meet the needs of a variety of students. There are two levels of FLCs in this grant: campus FLCs and discipline FLCs. These two levels enable faculty to discuss campus specific issues (e.g., specific challenges to students at different campuses) as well as to discuss discipline specific issues (e.g., how best to teach a specific content area). Overall, the FiTW grant has four goals with delineated outcomes:

- **Goal 1: Implement the flipped classroom model into freshmen and sophomore STEM gateway courses**
    - Outcome1. Quantitative and qualitative data about the effectiveness of the flipped classroom approach to teaching in freshmen and sophomore STEM gateway classes
    - Outcome 2. Student performance data in targeted STEM classes and performance in subsequent STEM classes
- **Goal 2: Evaluate the flipped classroom model at SJSU, CSULA, and CPP, all MSI campuses.**
    - Outcome 3. Quantitative and qualitative data about the effectiveness of the flipped classroom approach in freshmen and sophomore STEM gateway classes in comparison to student performance in traditional lecture classes
- **Goal 3: Strengthen STEM core academic performance in two key areas: retention and graduation**
    - Outcome 4. Increased retention of STEM majors at SJSU, CSULA, and CPP
- **Goal 4: Facilitate a culture of transformative pedagogical change among STEM faculty at the three CSUs**
    - Outcome 5. Increased number of STEM faculty at the 3 CSUs who are using active learning in their classrooms

<u>Course and Material Development for Calculus I and Physics I</u>

Development of materials for the core courses of the grant varies based on the extent to which materials already exist, the experience and expertise of the core faculty involved, and the discretion of the faculty for what they feel are the best approaches/resources to use for each topic. Most faculty are using a combination of existing resources and grant-developed materials. Training is being provided for faculty in both identifying quality existing resources and developing their own personal resources.

Calculus I faculty have largely developed their own series of lecture videos, course activities, and assignments/quizzes. One faculty member in the Calculus I group has taken the responsibility of developing most of the videos for the whole group, reflecting his level of comfort in front of the camera and his confidence with the technology used to create and edit the digital content. These videos tend to be very casual and entertaining, keeping the learning environment more light-hearted and easy-going. In-class activities have included assignments focused on practical applications of calculus in real-world examples, group work that encourages peer support, and mini-lectures at the close of class to reinforce concepts just practiced in the classroom.

Each Physics I faculty elected to create their own personal videos and materials to keep the courses more personal, as physics has one of the more developed libraries of digital content available for online instruction through both textbook and open access resources. One faculty member focused on developing content, lecture-type videos while another focused more on developing example videos to demonstrate the concepts and calculations. One faculty member also utilized the Quality Matters model to organize her course, with positive feedback from both the faculty member and the students on its use.

The experiences of the core faculty are being documented by the FLC Coordinators as part of the FLC activities and in anticipation using these experiences to guide our development of training materials geared towards the faculty across our institutions. Discussion of some faculty experiences can be found in the results section below.

Current Challenges

Over the first year of grant implementation, specific challenges have emerged. One critical challenge involves student readiness at the campuses for flipped learning. In these gateway courses, flipped learning provides for increased student-instructor contact, which is beneficial in terms of engagement, motivation, and persistence in the STEM course. Although students may get a lot of peer and faculty support within the classroom, some students may be challenged by the preparation for class (i.e., self-guided learning required prior to class). These students also have faced a lifetime of traditional lecture formats in their STEM courses (particularly URM students, whose prior classrooms are more likely to be under-resourced and less innovative). Thus, they may feel that they are not ‘getting much’ from their faculty and do not recognize or value the flipped approach. Faculty may, in fact, report that student ratings are affected by these perceptions, a noted major concern for young, probationary faculty.

Another challenge is using the flipped approach in large-lecture classrooms. Many gateway STEM courses are larger lectures, which opposes some of the core tenets of the flipped classroom. Faculty teaching larger STEM courses have reported difficulties in maintaining active learning with 80 or more students (that it creates a chaotic learning environment). Although research has shown effective use of the flipped approach in larger classrooms, greater discussion within the FLCs is planned to delineate more effective in-class activities for larger class formats.

A third challenge is maintaining communication in the discipline-specific FLCs. The faculty who teach these gateway STEM courses are feeling challenged in delivery the courses themselves and are more likely to reach out to the campus core faculty as opposed to the discipline-core faculty. This may be because campus core faculty have already established relationships whereas the discipline core faculty have met face-to-face only once and some have not maintained consistent contact. The FLC Coordinators are developing stronger strategies to enhance and facilitate community building across the three campuses.

Preliminary Results from the FiTW Grant

Basic Quantitative Results for Calculus I and Physics I

Preliminary results from the Year 1 FiTW activities at SJSU and CSULA are showing promise to improve passing rates of Calculus I and Physics I. Passing is defined as earning a grade of C or better, while failure is identified as either earning a C-, D, or F grade or failing to complete the course requirements and earning a W (withdrawal) or WU (unauthorized withdrawal). A C- was chosen as a failure grade because it is not considered a passing grade for the purposes of advancing to the next courses in the sequence when grades are part of the prerequisite requirements at SJSU (Physics and Calculus sequences), CPP (Calculus sequence only) and CSULA (Calculus sequence only).

Physics I shows mixed results in the success of the flipped classroom, with the method improving passing rates by approximately 9% at CSULA, maintaining passing rates at CPP (63.4% versus 65.7%) and potentially reducing passing rates at SJSU. See Table 2 for results. Additional information is being collected to determine what may have influenced the results in more detail. Variables being considered include demographics (race, at-risk category, Pell eligible, etc.), high school exposure to physics, Calculus I grades, and supplemental instruction. At SJSU, students have the option of enrolling in supplemental workshops and/or a preliminary physics course that introduces students to physics concepts if they have little or no physics exposure prior to college. At CSULA, the supplemental instruction is packaged with the physics course, making it mandatory for all students. The courses at SJSU were also disproportionate in their enrollment of repeat students. Table 3 shows that the flipped section had nearly 17% of the class repeating the course, while only 2% were repeating the course in the traditional lecture. It is unclear whether this influenced the instruction in the course, but further follow up will explore whether this influenced the pace of the course or the instruction. The flipped classroom mode of instruction did result in a higher percentage of the repeat students passing the course the second time taking it (75% in the traditional course versus 84% in the flipped course), a promising result for these highly at-risk students who already have experienced failure in the course.

	Total Students		Pass (A/B/C)				Fail (C-/D/F/W)			
	Trad	Flip	Trad	Flip	Trad	Flip	Trad	Flip	Trad	Flip
SJSU	179	187	142	125	79.3%	66.8%	37	62	20.7%	33.2%
CSULA	270	84	194	68	71.9%	81.0%	76	16	28.1%	19.0%
CPP W17	344	35	218	23	63.4%	65.7%	126	12	36.6%	34.3%

Table 2. Preliminary results for Physics I are mixed, with CSULA showing a slight improvement in failure rates and SJSU showing an increase in failure rates. Additional information is being sought to determine what may have influenced the results, including enrollment in supplemental workshops, grades in prerequisite courses, exposure to physics prior to college, and instructor ratings.

Section	Mode	Total Students	Pass	Fail	% Fail	Repeats	% Repeats	Repeats Pass	% Repeats Pass
1	**Trad**	179	142	37	20.7%	4	2.2%	3	75.0%
2	**FLIP**	187	125	62	33.2%	31	16.6%	26	83.9%

Table 3. The two sections of Physics I at SJSU were similar in size, but disproportionate in the number of repeat students (students who have previously taken the course and received a failing grade or failed to complete the course). While a greater number of students were repeaters in the flipped section, they were also more likely to pass the class the second time with the flipped instruction.

Flipping the Calculus I courses resulted in improved failure rates at all three schools, with SJSU improving their failure rate from 31% to nearly 19% (Table 4). CSULA improved only slightly from approximately 38% to 36%. CPP improved their failure rate in both terms, from 20.6% to 3.3% in Fall 2016 and from 35.8% to 15.6% in Winter 2017. Calculus I sections at CSULA averaged 25 students (Range: 16-30), while CPP Calculus I sections averaged 31 students (Range: 25-33). SJSU had 4 sections between 31 and 47 (average: 37) and one large section of 102. Size of the class did not appear to negatively affect the pass/fail results, with the large section at SJSU having a better-than-average failure rate of approximately 26%. Results are being analyzed further to determine if additional variables influenced the positive results, including enrollment in supplemental workshops, readiness for college-level math at acceptance, and instructor ratings. SJSU and CSULA have optional supplemental workshops for Calculus I courses, but neither university requires enrollment in the additional course. CPP does not currently offer supplemental workshops for Calculus I courses.

	Total Students		Pass (A/B/C)				Fail (C-/D/F/W)			
	Trad	**Flip**	**Trad**	**Flip**	**Trad**	**Flip**	**Trad**	**Flip**	**Trad**	**Flip**
SJSU	218	32	150	26	68.8%	81.3%	68	6	31.2%	18.8%
CSULA	346	25	216	16	62.4%	64.0%	130	9	37.6%	36.0%
CPP F16	281	30	223	29	79.4%	96.7%	58	1	20.6%	3.3%
CPP W17	240	32	154	27	64.2%	84.4%	86	5	35.8%	15.6%

Table 4. Preliminary results for Calculus I show a positive trend, with both SJSU and CSULA improving failure rates. Additional information is being sought to determine what may have influenced the results, including enrollment in supplemental workshops, readiness for college-level math at acceptance, and instructor ratings.
*CPP data is for quarter terms, not semesters, as is for SJSU and CSULA.

As grant activities progress, additional and more detailed data will be collected for these and all courses associated with the grant. A major study of student success in Calculus I, as defined by pass rate and success in subsequent courses, is planned in Year 3 of the grant in association with an external evaluator. This study will fully investigate the flipped classroom model, both quantitatively and qualitatively to validate the use of the methods on these campuses and the other campuses, as well as the training methods and materials developed. Design of the study is ongoing with external evaluator WestEd and is expected to meet the Department of Education's What Works Clearinghouse without reservations.

Qualitative Results on Instructor Experience

Core faculty involved in the grant participated in feedback sessions as part of their FLC activities at the end of the first active semester of the grant. Faculty provided meaningful, reflective responses about their FLC participation and flipping activities within a "What?/So What?/Now What?" framework. The questions were meant to focus the faculty member's attention to what they did, what it meant to their flipping journey, and what they would do differently or change moving forward. Faculty responses were very useful in developing FLC content for upcoming sessions, as well as guiding the decisions for what to include in training materials for the outreach training that will begin in Summer 2017. With regards to the FLC activities, faculty had the following constructive comments:

- In-person FLC activities were excellent for community building.
- Additional information and training on student engagement philosophy and methods would be very beneficial, especially for novice flippers.
- Regular contact initiated by FLC coordinators to facilitate communication with the

discipline FLC members was well received.
- Weekly, pre-planned video chat sessions were very useful in planning and collaborative development of materials, as well as assisting faculty in giving surveys to each others' classes so that feedback is less biased.
- Even for faculty who are far along the path in their flipping journey, the FLCs provide a great platform to talk to enthusiastic people, which improves your state of mind.
- Formalizing a mentoring program that pairs novice flippers with experienced flippers would be beneficial to encourage development through the challenges of flipping, practice implementation in mock lectures, and obtain formal feedback from class visits from faculty well-versed in flipped classroom for tenure, and promotion. Such a program would likely improve faculty adoption of active learning pedagogy, especially for probationary faculty who run the risk of lower instructor ratings for using a novel approach, are often subject to peer reviews from faculty who are inexperienced in active learning pedagogy, and are often novice instructors who lack confidence in their abilities.

In response to these comments, FLC Coordinators have begun developing additional content and modified communication methods of various activities. Among the changes include:
- Make communications as personal as possible by using video conferencing tools as often as possible to encourage more face-to-face interaction among FLC members, especially for discipline FLCs that are spread across the three campuses.
- Create a communication structure that is overseen by the FLC coordinators to ensure discipline FLC members are communicating frequently, especially during the development and implementation stages.
- Create evaluation instruments that will be useful for peers to review colleagues' flipped classroom courses in a helpful, organized format that highlights the key components of a flipped classroom.
- Develop a mentoring program that matches novice flippers with experienced flippers to create positive experiences for everyone involved in flipping activities.

Faculty reflections on their flipping experiences also provided useful guidance for the development of training materials. Some of the most useful comments include the following:
- Developing and testing a variety of materials provided useful information as to what activities and digital formats worked best for the class.
- Move away from in-class activities and clickers to project-based software tool that focused on application greatly enhanced the course.
- Utilize mini-lectures and in-class examples when appropriate to enhance the learning environment so as not to rely solely on students' self-paced learning outside of class for knowledge acquisition.
- Create meaningful in-class activities is harder that creating lecture videos and tutorials, so bringing attention to this aspect of flipping through FLC activities is critical to the success of implementing a flipped classroom.
- Flipping a class all at once is ill advised for novice flippers. Providing time management suggestions for flippers is important to help prevent burn out in material development.
- Focus more on what students need to learn, not what you are going to teach. This change in focus helps guide material development that is student-centric.
- Creating at least some personal videos is important for most flips to be successful, since it

allows for personalization of content and keeps the role of the instructor central to all aspects of the flipped classroom.

FLC Coordinators are taking these comments and creating training tools that support these observations and activities that faculty found most useful. The training tools will be developed with the intention of creating training workshops that are in the spirit of the flipped classroom, with online tutorials and videos that would serve as stand-along lessons if utilized outside of formal training, but would be greatly enhanced by in-person training sessions that focus on the implementation of the methods and development of materials. All training tools will be vetted through the training sessions through the grant and will be posted publically on a website tied to grant activities, which is currently in development.

Conclusions

The FiTW grant at San José State University, in partnership with California State University-Los Angeles, and California State Polytechnic University, Pomona, is focusing on creating a culture of change in STEM education through development of universal materials that meet the needs of a variety of students across the state. The grant activities are being used to validate the flipped classroom model's use in gateway STEM courses, encourage use of modern pedagogy in classes that alienate URM students and others who are at-risk, and develop Faculty Learning Communities where faculty can become agents of change through training and support of their peers. Current activities have identified several areas that would benefit from additional research and development, including an in-depth evaluation of the use of flipped classroom as a means of improving performance in gateway STEM courses at San José State University, California State University-Los Angeles, and California State Polytechnic University, Pomona, improved evaluation tools that faculty not trained in flipped classroom pedagogy can use to conduct peer evaluations for probationary faculty who are implementing the flipped classroom, and development of training materials that promote understanding of student engagement, paced implementation of the pedagogy, and collaboration with colleagues across institutions.

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