Lessons from a Lower Division Mathematics Co-Teaching Sequence

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Abstract

Students entering STEM programs at California State University, Bakersfield (CSUB) have a low level of mathematical preparation and a low awareness of the relationship between mathematics and their respective STEM disciplines. The majority of CSUB STEM majors start at a mathematics course below the lowest mathematics course required in the major. As part of an NSF IUSE grant to address persistence issues in STEM, CSUB piloted a co-teaching program between mathematics and STEM faculty in precalculus and calculus courses. The goal of the co-teaching program was to incorporate concepts from the STEM disciplines into the materials for the precalculus and calculus courses, which would then be used by mathematics faculty members when teaching the courses in the future.

The co-teaching program was considered successful, but it also presented challenges. Students reported their appreciation in seeing mathematics applied to science and engineering. Mathematics faculty members also appeared to gain a better understanding from their science and engineering colleagues on skills students need for success in STEM, while science and engineering faculty members gained a better understanding of the mathematics taught in each mathematics course. Challenges faced by the program were primarily administrative. They included variability in staffing, less availability of faculty members as the student body at CSUB expanded, faculty buy-in, faculty coordination challenges, and scheduling conflicts.

Introduction

CSUB is a mid-sized public comprehensive university, serving approximately 11,000 students, located in a region with low education achievement according to U.S. Census data [1]. As a result, students entering STEM programs have a low-level mathematical preparation and a low awareness of the relationship between mathematics and their respective STEM disciplines. The four-course sequence of precalculus and single variable calculus is a serious hurdle for students to succeed in their respective STEM majors. Pre-grant assessment data showed consistent low grades in this course sequence. Additionally, many students entering CSUB place at the precalculus level and many students repeat one or more courses in the sequence, which delays their progress in their STEM majors.

The majority of students taking the precalculus and calculus courses are STEM majors rather than mathematics majors. Co-teaching has been shown in literature to bring benefits to both students and teachers [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12]. CSUB piloted a co-teaching program between mathematics and STEM faculty in precalculus and calculus courses during the NSF IUSE grant to improve student success and persistence in STEM. The execution of the co-teaching program faced multiple challenges, both due to the nature of the program and to unrelated issues at CSUB during the grant period. Eventually, all classes were offered within the grant period.

In this paper, we discuss the lessons learned during the execution of the co-teaching program, including the challenges faced during the program, and the findings from assessment.

Program Details

In 2013, CSUB was awarded an NSF IUSE grant. One of the grant activities was a pilot co-teaching program between mathematics and STEM faculty members. The co-teaching program consists of two phases: co-teaching module development and module verification by mathematics faculty members.

For co-teaching module development, the program paired up mathematics faculty members teaching Precalculus 1, 2 (College Algebra and Trigonometry) and Calculus 1, 2 (Single Variable Calculus – Differential Calculus and Integral Calculus) with faculty members in each of the disciplines of Chemistry, Engineering, or Physics. Students in these classes were taught jointly by a mathematics faculty member and a faculty member in the respective STEM disciplines.

The goal of this phase was to incorporate concepts from the STEM disciplines into the materials for the mathematics course. Each co-teaching pair of faculty members was required to produce a set of six self-contained classroom activities that could be used by the mathematics faculty members when teaching the course in the future.

In the module verification phase, also called the standalone phase, another set of mathematics-faculty members used the products from the module development phase in their own courses, without a STEM co-teacher, to test the activities. The mathematics faculty members provided feedback about the modules, and another mathematics faculty member was enlisted to further refine the modules in response to the feedback.

Since the conclusion of the program, the developed modules have been available to all mathematics faculty members if they wish to use them in their classes.

Assessment Methods

Qualitative data was collected in the co-teaching classes through surveys and interviews with students and faculty members separately. Faculty interviews were conducted throughout the grant program period and at the conclusion of the program. The internal evaluator also conducted follow-up interviews with faculty members during Fall 2019 asking them about their perspectives on the co-teaching experience or module verification experience. Faculty members were asked about challenges in the co-teaching experience, delivery of instruction materials, further adaptation of the materials after the program, the benefits and experience from the co-teaching program, and for any advice or lessons that could be shared with the program director and other faculty members. The authors analyzed the interview transcripts and survey data in [13] to summarize findings in this co-teaching strategy.

Administrative Challenges

The plan for co-teaching involved four departments: Mathematics, Chemistry, Computer Engineering, and Physics. Even though each department was consulted during the grant proposal writing stage, due to department chair and staffing changes, plans to execute the program had to be renegotiated with each department after the grant was awarded.

The staffing of classes was an immediate challenge. Within the Mathematics Department, precalculus courses were originally agreed to be taught by tenured and tenure-track faculty

members, but eventually had to be taught by lecturers due to a shortage of teaching personnel and an increase in enrollment demand. Therefore, staffing of these courses were frequently arranged at the last minute and the instructor assigned to the courses was volatile.

In addition, the lecturers who were hired to teach these courses had to be asked about their willingness to participate in the program, and the designated co-teaching STEM faculty member had to be willing and available to work with the lecturer. The specific sections each term where co-teaching was piloted changed as a result of these issues, including available time slots for both faculty members.

In the case when a planned co-teaching section a particular class could not happen due to these issues, the class was postponed for a term. Ultimately, the co-teaching classes were completed in 6 terms, instead of the originally planned 4 terms. Table 1 has the full schedule of co-teaching courses listed by the terms in which the co-teaching actually occurred.

Table 1: List of co-teaching sections where co-teaching modules were developed

STEM Discipline	Mathematics Class	Term Co-teaching Course was Offered
Chemistry	Precalculus 1	Spring 2015
	Precalculus 2	Winter 2015
	Calculus 1	Fall 2015
	Calculus 2	Fall 2015
Engineering	Precalculus 1	Winter 2015
	Precalculus 2	Spring 2015
	Calculus 1	Spring 2016
	Calculus 2	Winter 2016
Physics	Precalculus 1	Winter 2016
	Precalculus 2	Fall 2015
	Calculus 1	Spring 2016
	Calculus 2	Spring 2017

Scheduling standalone sections where a mathematics faculty member verified the developed modules also faced the same mathematics faculty issues note above for the co-teaching module development phase. The chemistry faculty member who had participated in the co-teaching phase had also left CSUB before the verification phase and was not available to answer any questions about the modules. Due to these challenges, the standalone phase was redesigned to primarily focus on Precalculus 1, Precalculus 2, and Calculus 1 with the physics and engineering modules. Table 2 has the full schedule of module verification.

Table 2: List of standalone sections where co-teaching modules were verified

Mathematics Class	STEM Discipline	Term Standalone Course was Offered
Precalculus 1	Engineering	Spring 2017
	Physics	Spring 2016 and Fall 2016
Precalculus 2	Engineering	Spring 2016, Fall 2016, and Fall 2017
	Mixed	Spring 2017
Calculus 1	Engineering	Spring 2017
	Physics	Fall 2016
	Mixed	Fall 2017, Fall 2018
Calculus 2	Mixed	Fall 2018

The original grant plan was to offer release time to faculty members participating in the co-teaching sections. Due to increased enrollments of STEM majors at CSUB during the grant period, departments could not always fully staff their courses if the co-teaching faculty received the original release time. Some release time was converted to stipend pay, with the agreement of participating faculty.

An additional administrative challenge was the conversion of CSUB from the quarter-system to the semester-system in Fall 2016. Campus administration announced the conversion in Fall 2013, shortly after the NSF IUSE grant was received. This led to difficulty in getting faculty buy-in, as they were busy planning the conversion of their own courses or they might not have seen the benefit to incorporating new pedagogy if they had to redo the mathematics courses in Fall 2016 anyways. From a grant assessment perspective, this also made it difficult to compare outcomes in the grant-supported sections to historical data for the courses, since there was some shift in course content and students were taking more courses per term under semesters. For example, the average grade for the grant-supported sections under quarters was higher than the baseline for Precalculus I, Precalculus II, and Calculus 1, but all grant-supported sections under semesters were less than or equal to the baseline. The average GPA at CSUB also decreased in Fall 2016, which suggests that students were primarily struggling with the semester conversion rather than facing any specific issues in the grant-supported mathematics courses.

In summary, multiple administrative challenges led to changes in both the schedule of co-teaching sections and the approach to verifying modules. Most of these administrative challenges were related to staffing issues. While the grant had sufficient funding to support the program through faculty release time, it did not contain funding to hire new faculty members. CSUB faced a large growth in STEM enrollments during the grant period, which put increasing time pressures on existing faculty members and led to a stronger reliance on lecturers for staffing precalculus and calculus courses.

Faculty Observations: Challenges

The primary challenge noted by faculty members in interviews related to coordinating with one another. As mentioned in the previous section, mathematics faculty were often assigned at the last minute to the precalculus and calculus courses. As a result, these faculty members often had very little time to prepare for the class, much less to engage in innovative pedagogies. To adapt to this reality, in some cases the co-teaching was delayed and only began after the third week of instructions. This gave the mathematics faculty member sufficient time to fully settle in their class before working with the STEM faculty member.

One engineering faculty noted: “The challenge regarding co-teaching, is the coordination. In a system like this university, it is easier to coordinate with another faculty. We have so many lecturers, part-time lecturers. When you talk about lower-division courses, there are so many different faculty, that the coordination is difficult. In my opinion, with the grant we had in particular, someone like me would develop the materials (modules). If the material is there, maybe they coordinate it. It is not only the co-teaching, this (modules) is what you need to follow. That (coordination) is what would make it easier. Otherwise, if I am a part-time lecturer, I am not so invested. I might not turn my class around (use the modules). I might be reluctant to do so.”

Faculty Observations: Benefits

In general, the STEM faculty members found co-teaching highly beneficial to their understanding of what students would know from the precalculus and calculus sequence. In other words, they gained a better understanding of the mathematics knowledge students should have entering the STEM courses, rather than what they thought students should know based off what they learned when they were a student.

STEM faculty members also learned what is needed to refresh the mathematics skills for the students in their courses. One faculty member mentioned that it is hard to determine the course delivery simply by looking at the syllabus. Co-teaching enabled him to understand the expectations in the mathematics class. He also indicated that some of the modules that were developed can also be used in his science classes.

The mathematics faculty members found the experience informative. They learned what particular topics are more important to the STEM disciplines and learned to emphasize the applications of the mathematics concepts while teaching. One faculty member indicated that in precalculus, most of the students were freshmen and they may not have the vision about to know how the mathematics concepts could be used in the future for their major. The co-teaching experience exposes students to "more concrete ideas, why they have to study mathematics to complete their degree," and it is "a great opportunity for them to realize how these areas are connected."

According to a physics faculty, "The math teacher teaches certain math courses. They tell me they are teaching this chapter today. Based upon that chapter, I would come up with a physics problem that fits with that math. I am not applying the same thing (not teaching math) in the same way. It helps me, when I am teaching physics, the maturity (math knowledge) of the student - they do not follow - it is not because of the physics problem - they have a poor math quality (knowledge) for level of math. Frequently, when I am teaching physics, and I go to the detail of the math I am using. They have taken the math one or two semesters ago. I cannot go to each chapter of the math and demand everything (knowledge of the past math courses). Now I know what math they have done. I have gone through the calculus and non-calculus-based math books. If you (students) forget this, I am applying this (physics application). If you (students) forgot this (math), you could go to the math book. Whatever I need here (physics lesson), I can do a quick review of the math. Time is a limitation. I cannot spend too much time on math, or I will not get through my physics problems. (Over all, my knowledge of what math the students have had) this is helpful. I better understand what kind of math the students have done."

Another mathematics faculty indicated, "I do like the Engineering aspect. That was great. The (math) students were constantly asking where it (math applications) is appropriate. Having those modules available is useful when showing students the applicability. I am going to be teaching the Bio-calculus, and even though that is not engineering focused, that is the type of thing I'm going to steal when I am getting ready to teach, regular Calculus as well, just because it is a better idea for the students."

Most of the mathematics faculty who used the co-teaching modules did not report any problems. However, more time and trials are needed to refine the modules. One faculty member mentioned the difficulty of adapting to use the modules for the first time: "I wasn't prepared to use them. Because I hadn't prepared them - dropping them in. Timing was off

for me. When I use them again, I would definitely incorporate them in a better way than I did. That was much more of a reflection upon me than the modules themselves. We get in a routine and dropping something in is difficult for me. I would recommend that they prepare to drop those in."

In summary, both mathematics and STEM faculty members found value in the co-teaching experience. The experience has created a cooperative culture between faculty members that has led to benefits for both faculty members and students. In addition to gaining better insight into each other's disciplines, several faculty members remarked about how the model is adaptable to other situations.

Student Observations

In interviews conducted by the external evaluator, students indicated they enjoyed the STEM professor coming into the classroom and giving them practical STEM problems that brought the mathematics alive. Students also found the interactions between the mathematics and STEM faculty members enlightening. The students appreciated how the faculty members worked together to understand and appreciate their different perspectives on how best to use the co-teaching modules. Students also noted that with three resources in the classroom (two faculty members and a student assistant), they were able to receive help and get different perspectives that provided context while learning new material. As was noted in one interview, "The science professor shows them how the math applies to his discipline -- so you are exposed to how scientists use the skills in their teaching and research."

Faculty Advice

One advice from the faculty members was to have two or more co-teaching sections per STEM discipline and mathematics course combinations. Due to the challenges faced by the grant program, there could only be one co-teaching section per discipline and mathematics course combination. It is more beneficial for the paired faculty members to co-teach the same course two times, or more. Such a change would help faculty to refine their work, and experiment alternatives to approaches and examples that did not work as expected.

Another advice from the faculty members was making the co-teaching modules an ungraded part of the course. As one faculty indicated, the application of mathematics to STEM is intended to improve the learning process, while graded assignments can be very stressful for students. An ungraded assignment takes away the stress and pressure of getting a good grade. By taking the pressures off of students having to master the module, it is easier to let students enjoy the material. The faculty member noted that this "changed the mood of the classroom."

Conclusion

In conclusion, the authors have the following advice for people designing co-teaching programs:

1. Develop a flexible, easily modified co-teaching schedule, as scheduling and staffing issues always happen.
2. Use a flexible faculty compensation scheme. Each faculty member has a different preference on release time or monetary compensation.

3. Incorporate a longer co-teaching program with multiple instances of each paired co-teaching team, to give sufficient time to refine products.
4. Any extra materials introduced should not be part of the graded curriculum. This makes the learning less stressful.

Acknowledgment

This paper is based upon work supported by the National Science Foundation under Grant No. 1430398. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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