

# Coordinating IBL and non-IBL Calculus II

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**Abstract**—Increasing amounts of research support the efficacy of inquiry and projects based learning. However, teaching via inquiry can be challenging for an individual instructor to adopt in a highly coordinated environment where a course is taught by multiple instructors, and all sections are expected to follow a common syllabus and take a common final exam. In this paper, we describe our efforts to make space for an inquiry approach to teaching calculus within this constrained environment where the new approach is not adopted by all instructors. Our efforts started with the collection, adaption and development of materials to cover the topics already defined for the course. We piloted our materials with a small group of instructors in the first semester and then opened up the materials to other instructors in subsequent semesters. We have now implemented this method over the past four semesters. Through this process we have shown that the integration of inquiry methods and projects within the pedagogy of individual instructors can be effective, but efforts should be taken to ensure the timing of instruction and coverage of materials is comparable to the efforts of colleagues teaching via lecture methods.

## BACKGROUND AND MOTIVATION

One of the goals in the Naval Academy’s Master Academic Plan is to increase the use of project-based and experiential learning, especially in the core courses. In a convocation to the faculty in August 2017, Naval Academy Superintendent Vice Admiral Carter twice mentioned his desire to increase “projects based learning” in classrooms at the Naval Academy. He also encouraged faculty to provide their students more opportunities to speak up and present materials in class.

In mathematics nationwide there is a growing community of practitioners of Inquiry-Based Learning (IBL). Inquiry-based learning takes many forms, but the two key features (“twin pillars”), supported by the research of Laursen et al [7], [8] are 1) students have opportunities to collaborate, and 2) students engage deeply with rich mathematical tasks. In a typical IBL class, students work through a carefully built sequence of investigations, while the teacher acts as a coach. The students may be doing these investigations during class in small groups, or individually before class. The class as a whole then comes together for a discussion, in which students explain their ideas to each other, and as a group refine their thinking. Another important feature of IBL is that instructors use their observations of student thinking to make decisions about the class. Some of these decisions are made minute-by-minute, such as in deciding what hint to give, choosing which student to present, or asking a key question. This approach

to teaching and learning has been demonstrated to improve student learning, especially for women and for previously low-achieving students [1], [3], [7], [8], [10].

IBL is one of many varieties of active learning. Active learning more generally has been shown to be extremely effective, and is increasingly widely accepted as being good for student learning [5], [9]. One meta analysis by Freeman et al stated that the effects of active learning techniques compared against purely lecture methods had such a significant affect on student learning that if it was a medical study it would have been stopped for benefit [5].

However, instructors who wish to use IBL or other forms of student centered, active learning in core mathematics courses at the Naval Academy have faced an uphill battle. The coordinator for each core course provides a syllabus that includes a daily calendar showing which sections of the textbook are to be covered and which homework problems are to be assigned. In principle, each instructor can cover this material in any way they choose. In a previous project [4], the third author and colleagues created individual activities that could replace a day or two in the syllabus. But in practice, there is strong pressure to “keep up with the syllabus,” which leaves little time for student investigations. There has come to be a strong expectation, among students and faculty alike, that instructors will spend each class day explaining to students how to do that days homework problems.

The goal of our project was to create an alternative. We built a framework that would allow new instructors to more easily adopt an active, and inquiry-based mode of teaching. We also created a model for course coordination in which instructors have more freedom to teach in the way that works best for them and their students.

## I. DESIGNING THE COURSE

We decided that of the core math courses at the Naval Academy, Calculus II was the one in most need of attention. We started from the list of topics covered by the course, and worked to assemble a set of inquiry-based activities that would cover the same set of topics. We adopted many of the IBL Calculus II activities written by Mairead Greene and Paula Shorter [6]. We also adopted some “TACTivities” from the Boulder-Omaha Active Learning Alliance. [2]. We then wrote our own activities to cover the topics of ratio test, comparison

test, work, partial fractions, polar coordinates, and vectors and three-dimensional analytic geometry.

We tried when possible to incorporate a hands-on, physical component to activities. We printed large shapes on foam core for students to estimate areas. We borrowed springs from the physics department for the work unit, and encouraged students to stand on their desks during the unit on three-dimensional coordinate systems.

Most of the activities we used were designed to be done during class, with students working in small groups. Thus most of our class time was spent on group work, punctuated by individual groups reporting out and whole-class discussions guided by the instructor. One exception was the 8-10 day unit on vectors, in which the students were asked to work problems individually before class, then present solutions one by one during class.

We kept much of the exam and grading structure the same as it had been. All students took a common final exam. Usually there are also four midterm “hour tests.” Our first semester of running the course, we replaced one of these tests with a paper, but in subsequent semesters went back to giving four tests. Each instructor writes their own hour tests, decides whether and how to grade homework, quizzes, class participation, etc., and decides how these are all weighted in the final course grade. Generally speaking the final exam counts for between 25% and 40% of the course grade.

## II. COORDINATION AND INSTRUCTOR SUPPORT

We debuted the inquiry-based version of Calculus II in the fall of 2016. The third author, who was part of the team developing the projects, also served as the course coordinator. During the summer, we developed a detailed set of learning objectives for the course. Some of these had previously been explicitly stated in course syllabi; others were implied by the choices of textbook sections and homework problems. We pared down the set of learning objectives as much as possible, for example leaving out explicit treatment of improper integrals, approximate integration, and  $p$ -series. (These topics were later added back in.) We then wrote an official syllabus for the course which listed the objectives, and a separate “Suggested Course Calendar” document which laid out two possible plans. One plan was a list of which IBL activities would take place on different days, and the other a more traditional list of textbook sections and homework problems. When it came time to write the final exam, it was based on the list of learning objectives from the syllabus.

During the fall of 2016, the four authors used the IBL activities, teaching 11 of the 17 sections of the course; three other instructors followed the textbook. In the second semester of this project, spring 2017, the third author was again the course coordinator. Another instructor was inspired to use the IBL projects, making a total of five out of nine, teaching 12 of the 22 sections.

In the summer of 2017, a sixth instructor chose to use the projects for a summer school course. In the fall, there was a new course coordinator who did not want to use the IBL

activities. The fourth author worked with the new coordinator to create the same kind of parallel IBL and textbook course calendars, which allowed 9 of the 17 sections to continue to be taught using the projects. Currently, in the spring of 2018, the fourth author is coordinating Calculus II and has written parallel calendars that include all of the topics that had been left out of the course during the first iteration.

In the fall of 2017, the four of us met weekly and walked through the IBL activities our students would be doing later that week. We also discussed what had happened in the previous week and how the class was going. These meetings were hugely beneficial, helping us to iron out both mathematical and pedagogical details. We found that an hour of meeting together was worth more than an hour of individual class preparation.

In the spring, the weekly meetings were opened to all course instructors, as well as tutors from the Center for Academic Excellence, some of whom were teaching one-hour extra help classes. The larger meetings had the benefit of improved communication between the IBL and non-IBL instructors. However, we were no longer able to talk about IBL-specific pedagogical issues.

## III. RESULTS, RECOMMENDATIONS, AND FUTURE WORK

As stated in the beginning, one of our goals was to reduce the barriers for instructors to adopt an IBL framework in their class. Since the start of the project, we have had several instructors adopt the IBL activities. The first author jumped in when he arrived at the Naval Academy. A Marine Corps major observed what we were doing the first semester and joined in for the second, and a Navy LCDR from the oceanography department joined in in the summer. During the second year, many instructors used some of the activities, or wrote their own adaptations of them. So we feel that this aspect of the project has been a success.

Having two “versions” of the course posed challenges. It was more difficult for students to find study partners outside of class. It was challenging for the instructors in the Center for Academic Excellence, both those doing individual tutoring and those doing one-hour extra help classes, because their clientele was split and working on different problems at the same time. Students’ opinions of the course also suffered from a “grass is greener” phenomenon. Supporting the Academic Center, and our own instructors, in addressing these challenges became part of the project.

Nonetheless, we hope future coordinators for all of the calculus classes will continue to separate the syllabus from the course calendar. We feel that this is an important gesture towards instructor autonomy. In the fall of 2018, both Calculus I and Calculus II are scheduled to have inquiry-based versions.

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