

# Students as Partners in Curricular Design: Creation of Student-Generated Calculus Projects

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## Abstract

In recent years advanced undergraduate students have developed projects for our redesigned Calculus II classes. Our student designers create new mathematics projects and present their work at conferences and in local talks. They are often mathematically early in their college careers, and so we can involve students of all levels in research projects.

Our course redesign affected three groups of students: those taking the class, those designing projects for the course, and embedded tutors. This qualitative study examines how the second and third groups of students benefited from their experiences and how we can modify our program to improve it. Evidence was gathered from interviews, surveys, and observation of student research work and its implementation in the classroom. Tutors reported more confidence in their knowledge of calculus and insights into teaching it, and project designers experienced benefits similar to that of a traditional undergraduate research experience.

## Introduction

The extensive use of undergraduate research in mathematics is fairly recent, dating back to the 1980s with the widespread introduction of the NSF-funded Research Experience for Undergraduates programs (Lopatto 2010). Most of these experiences are designed for advanced undergraduates who are in their junior or senior years, and they are often used to help prepare these students for graduate study. By using undergraduate students to develop projects for use in a Calculus II classroom, we can give freshmen and sophomores the opportunity to work on research. The purpose of their research is clear; our students are motivated by helping their peers learn. Developing the calculus projects as well as using them to teach calculus helps to contextualize the mathematics curriculum, which is seen as "a promising direction for accelerating the progress of academically underprepared college students" (Perin 2011).

The use of undergraduates as embedded peer tutors is common; see e.g. Evans et al. (2001) and Goff and Lahme (2003). Tutors attend most classes, and depending

on the instructor, sometimes work with students during the class sessions. Tutors can connect more deeply with the material, increasing their calculus skills as well as their ability to communicate and collaborate effectively.

In order to avoid ambiguity, we use "embedded tutors" or simply "tutors" to refer to the embedded peer tutors and "project designers" or "student researchers" to refer to students who, after completing Calculus II themselves, worked on researching a project for use in a future Calculus II course. We refer to students who were currently taking the course simply as calculus students.

In the section *Connecting Students to the Course*, we briefly describe our Calculus II course and the overall role of the tutors and project designers. As this varied by semester, we elaborate with more details and context in the *Experiences and Results* section. In the section *Curricular Design as Student Research*, we discuss definitions of student research that occur in the literature and how these connect to our curricular design. In the *Methodology* section we describe the methodology used in our study. In the *Experiences and Results* section, we delve into the results of the study, providing and elaborating on themes found in the student responses. In the *Conclusions* section, we summarize our results with a list of best practices.

### *Connecting Students to the Course*

At Roosevelt University, semester-long projects with a civic engagement component became a regular part of all sections of Calculus II in Spring 2010 (González-Arévalo and Pivarski 2013). Calculus projects help students explore STEM applications, acquire library research skills, and develop communication skills. Beginning in Fall 2010 each class was assigned an embedded undergraduate tutor who attended class at least once a week and helped students in and out of class. Starting in Summer 2011, undergraduate research students had the opportunity to work on designing materials for class projects. Their work involved picking a topic of civic importance, finding appropriate data sources, considering issues related to calculus, and linking these together. There are many possible outcomes for these projects: use in a Calculus II class, honors theses, research talks, and starter ideas for more advanced mathematical research. We consider all of these to be successful outcomes. We also had some unsuccessful outcomes where students failed to progress.

This course redesign originally developed as a result of our involvement with the Science Education for New Civic Engagements and Responsibilities (SENCER) project. Over the years, our continued involvement with SENCER helped us incorporate students as partners in our curricular design. At the end of 2013 we published a project report (González-Arévalo and Pivarski 2013) detailing the redesign of the course and what we then thought would be the benefits. The current paper provides a qualitative assessment of the newest components of this redesign, namely calculus project development by advanced undergraduate research students and the incorporation of embedded tutors. We provide a description of how we use the embedded tutors in class, as well as how students work on the design of calculus projects. Some of this is explained in our aforementioned project report but we have included it here also for the convenience of the reader.

### **EMBEDDED TUTORS**

Each semester at Roosevelt University there are one or two Calculus II sections, each with between nine and thirty students. Because there are only one or two calculus tutors per semester, we do not have a formal tutor training process. Each section instructor informally trains their own tutor. Typically, an experienced instructor acts as a secondary faculty resource. The designers do not work directly with the tutors, except in the cases where an individual student acts in both roles. In that instance, the tutor has a deep knowledge of the goals of the calculus project; we elaborate on this in the section *Theme A: Insight into better learning processes*. We intend for tutors to

- + attend all classes,
- + hold regular office hours,
- + test out the computer labs ahead of time, and
- + work with groups both inside and outside of class.

In practice, we often are unable to find qualified students whose schedule allows them to attend all class meetings, and so we loosen the requirement to attendance at least once per week. Tutors are not needed as graders, as the homework is online. Instructors grade weekly quizzes by hand to gauge where the class is mathematically. Instructors also grade the project parts. Tutors are student

workers paid hourly; their salary is part of the institutional budget, often including Federal Work Study. The use of the tutor varies by instructor. Some embedded tutors help students when they are working on problems during class, but others merely observe the class. When they are made available, some tutors try the class's computer assignments ahead of time. The tutors always help out during class periods involving computer use.

### PROJECT DESIGNERS

At Roosevelt University many students transfer in or take calculus their sophomore year, which means they are not ready for a traditional undergraduate research experience until their senior year. Therefore, students need to have research opportunities requiring less background knowledge. Project creation allows student researchers to choose an area for the calculus application.

In the initial course redesign process, research students compiled a literature review on calculus projects. This review and previous semesters' calculus projects provide a foundation for our project designers. Although they are mathematically constrained to construct a modeling project for a calculus class, designers independently explore an application of their own choosing. We ask that it involve actual data and ideally a social justice component. As they develop their plans, we meet weekly with the research students to discuss their ideas, progress, and challenges. During the week, they work independently, although we are always available either in person or by e-mail. At Roosevelt, students are funded through an NSF STEP grant (Science, Technology, Engineering, and Mathematics Talent Expansion Program) shared with the sciences, and through our university's honors program. At a school without funding, project design can act as an independent study project.

Some students had their own ideas for projects, and others modified existing projects. For example, one student found a project that involved studying population growth through a series of biology experiments. She wanted the project to be compelling to the many science majors taking the class. The original project involved studying population growth in simple life forms and in humans. Since growing cell cultures involved more lab time than was realistic for a calculus class, she arranged to use some existing yeast data from one of our biologists'

research labs. She investigated curve fitting with MAPLE, split the problem into discrete assignments, and structured the investigation to fit the topic schedule of the calculus course. We helped her with this process over the summer and made adjustments during the semester that we used her project.

Design typically happened over the summer, but it sometimes occurred during the semester. At any given time there are at most two students working on design. Although they had access to them, the designers did not formally review past projects, and they did not have formal discussions with tutors. They instead drew informally from their own experiences and anecdotes from their friends. The designers whose projects were used in courses saw the results of the students' work through a STEM poster session.

### Curricular Design as Student Research

The work that our students do creating calculus projects is a distinctive research experience that has much in common with a traditional undergraduate research experience. In the report "Mathematics Research by Undergraduates: Costs and Benefits to Faculty and the Institution" (MAA CUPM 2006), the Committee on the Undergraduate Program in Mathematics of the Mathematical Association of America lists four characteristics of undergraduate mathematics research:

- + The student is engaged in original work in pure or applied mathematics.
- + The student understands and works on a problem of current research interest.
- + The activity simulates publishable mathematical work even if the outcome is not publishable.
- + The topic addressed is significantly beyond the standard undergraduate curriculum.

Although these guidelines were originally designed to describe a traditional mathematics research project, they apply in many ways to the work that our research students do. Our research students create projects for use in a Calculus II classroom, and so theirs is more of an applied curricular design research project than a traditional mathematics research project. Because of this, the first item is only partly true; the work is often adapted for a Calculus II classroom from another

source. The second item holds, and it was a significant motivator for our research students when they chose the topic of their project. The third holds in the sense that their work, when completed, is made public through use in our classrooms. This is similar to an applied project being used by a company. For our students, two of six projects reached this point. Others either lacked time or good data sets or transitioned from a Calculus II project into applied math research for an honors thesis. The final point applies in the sense that it takes them outside the traditional curriculum. While the mathematics might be found in an undergraduate math modeling course, the act of designing mathematics activities that relate to a social justice theme provides a deeper challenge. At the same time, this allows our student project designers the chance to work on research very early in their undergraduate studies.

**Dietz (2013, 839) defines three levels of student research activities:**

**Guided discovery:** In these classroom activities, students make step-by-step progress toward a standard (but unknown to them) mathematical formula, or other result, via open-ended, but guided questions.

**Independent investigation:** In these multi-day activities, the instructor asks open-ended questions that require independent exploration by the students. Results may not be surprising to professionals, but they cannot be easily found in the literature.

**Scholarly inquiry:** In these intense activities, students engage in scholarly work that is typical of a given field of inquiry.

Our research students engage in curriculum design, researching applied areas and educational theories in order to develop a guided discovery project for the Calculus II class. The process of creating a new calculus project is an independent investigation; for one of the students it moved beyond this into the area of scholarly inquiry where she analyzed the efficacy of her project. For another, her work extended beyond that of a typical

Calculus II project and became scholarly inquiry in the area of actuarial science.

There are multiple layers of learning, where advanced students progress beyond Calculus II while helping students currently taking Calculus II. When surveying the literature, we have found a few instances where advanced students created mathematics materials for introductory students. In Duah and Croft (2012), four mathematics students worked with lecturers to create materials for a module in vector spaces and complex variables. The authors noted the call for student-led curricular design in the UK (Kay et al. 2007; Porter 2008), which other fields have responded to. The authors also noted that there was a paucity of literature on student-created mathematics curricula. At least two papers were written in response to Duah and Croft (2012). In Hernandez-Martinez (2013), two students at an English university worked to create mathematical modeling teaching and assessment tasks for a second-year mathematics for engineers course. In Swinburne University of Technology in Australia (Loch and Lamborn 2015), a team of engineering and multimedia students created videos for engineering students to demonstrate how mathematics is used in engineering. In Pinter-Lucke (1993), the program of Academic Excellence Workshops (AEW) at Cal Poly Pomona involved STEM upperclassmen as leaders of cooperative learning-based workshops for underclassmen in courses ranging from college algebra through calculus. Student facilitators selected materials and led weekly problem sessions. The facilitators met weekly with faculty who were teaching the course, and they went to an intensive two-day training session. Although the paper does not mention whether the problems are student-created or student-selected, the process of choosing appropriate course materials is an advanced one, and so this is a notable example of students contributing to the enhancement of mathematics curricula.

Some institutions involved with the SENCER project are also working with students to create curricular materials, notably in biology (Goldey et al. 2012), where students are used to create and update labs. At Guilford College students are creating a new course as a part of their independent study, and at New England College a proposal is being piloted. At the United States Military Academy students are doing in-depth assessment



research of the university's curricular design across the STEM disciplines (United States Military Academy 2014).

In many of these cases, a small number of students were selected to participate in this work, but without a particular common experience to draw upon. In our project we bring students into the experience systematically and intentionally, which leads to the following multi-level learning experience: students have the initial experience of working on a Calculus II project as students in the class, then are given the opportunity to work as a peer tutor or project designer (or both). Their subsequent work then impacts the next set of potential tutors and designers. The depth and detail of the work done by our project designers appears to go beyond that of the AEW leaders, and so the combination of multi-level learning with the depth of experience appears to be unique to our endeavor.

## Methodology

In this qualitative study, which received IRB approval, we interviewed each student with several open-ended questions (Appendix A) to get them to reflect on how they were affected by the experience.

We created a survey after we interviewed a few of the students, and it included questions that were based on the interviews. The survey itself was anonymous, and it was used to corroborate the interviews. This qualitative study involves a relatively small number of potential subjects: six project designers, one of whom was also a tutor, and eight additional students who were embedded tutors. Eight students, four of whom were project designers, agreed to be interviewed; four of these also completed a follow up survey. Two individuals, including one project designer, completed the survey, but not an interview. Four did not respond to our contact request. Due to the small sample size it was not possible to conduct a quantitative study of these results, and we have therefore avoided all numerical data throughout the paper (since it would not be statistically valid). Instead, we present the results of the qualitative study of the interviews. The survey was only used to triangulate the results of the interviews.

To categorize the responses, the three authors independently reviewed the interview transcripts and labeled responses according to a variety of categories

(Appendix B). The labels were compared and discussed until consensus was reached. The results are organized into three main themes as follows:

**Theme A:** Insight into better learning processes.

**Theme B:** Insight into applying mathematics/calculus.

**Theme C:** Feedback on improving the experience of embedded tutors and researchers.

## Experiences and Results

In the first part of this section we will describe some of our observations made as course instructors and research advisors. In the second part of the section we will concentrate on the actual results of our interviews.

### Experiences

Overall, our experiences have been positive. While some of our embedded tutors merely benefited from a review of calculus, others developed into expert teachers. All students surveyed confirmed that they gained in some way in varying amounts.

At the beginning, we hoped that the use of tutors would contribute to a sense of community among the students in the class and in our major. We also hoped that the class's mathematical skill level would increase along with the tutor's mathematical skills. We hoped for smoother computer labs, smoother group dynamics during the project, and a source of peer advice. Two of the tutors explicitly commented on the increased sense of community; we observed this as well, both in the classroom and among the tutors. Due to the small number of class sections observed it was difficult to discern whether embedded tutors consistently improved the mathematical skill level of the class and to assess their group dynamics. But tutors had a noticeable effect on the computer labs; these benefited greatly from the extra support. The amount of peer advice given varied by tutor; some of them commented on this in the interviews. Students in sections where the embedded tutors helped during the class period appeared to be more likely to work with the tutors outside of class.

There has not been a good mechanism for class feedback on the tutors; an online survey had a low response rate, but informally they praised tutors who were actively involved.

Our experiences with student researchers have also been mixed. They have definitely learned the difficulty of finding data, since much of what is found online is processed data that give only means, medians, and standard deviations rather than raw data. They found that government sites are usually a good data source. As a result of their work, we used two student-created projects in our course; these are on modeling population and modeling air pollution. Those student researchers gave talks on their projects, both internally and externally. Two students developed more involved research projects on actuarial and head injury models that were not used in class because they were too advanced for a Calculus II class but which resulted in internal and external talks. Two projects (population, actuarial modeling) developed into honors theses, with the first thesis also studying the impact of the population project on the class using it. Two projects were not finished. One of the student researchers, working on temperatures, was stalled in the data collection stage, and did not relate the topic to calculus. The other, working on planetary motion, had planned activities but lost the plans in a move. After this, we started making students type up their results part-way through their research project to prevent the loss of work. In our experience, project designers have the best results when they fill out weekly timesheets rather than being paid in a lump sum for their summer research. Timesheets appear to help with their pacing and accountability. In a situation where a designer is working in an independent study, the structure of the independent study course can be used to aid in pacing.

## Results

The student interviews indicate that the students benefited from their experience as tutors and designers as well as from working on the Calculus II projects. They also provide valuable feedback on the curricular design. Note that we have removed words such as “Uh, um, like” as well as repeated phrases from the transcription quotes without explicitly labeling each occurrence.

## THEME A: INSIGHT INTO BETTER LEARNING PROCESSES

This theme encompasses the students' sense of themselves as learners and tutors, how math instruction is enhanced by students working on open-ended problems, and the components of effective project design. All of the tutors and designers report gains in their understanding of calculus and in becoming better students themselves. All appreciate the value of a required Calculus II project.

Tutors and designers put considerable thought into what students need to be successful. All of the tutors helped with the technology. One noted that they wanted students to see that the computer is doing something you can do by hand but just much faster. Tutors noted the value of learning to work in teams and that talking about a project is a good way to communicate to outside people what you learned in the class. Tutors noted the value of sitting through the class a second time. They were able to work on their problem areas and to look for connections among the topics and applications. Having experienced the challenge of working on a project that is more open-ended than a typical homework problem, they are in a position to coach students through the process. One tutor spoke at length about the psychology of a student facing a difficult subject. Knowing that their tutor struggled with calculus when they first took the class can reduce the student's own stress and self-doubt.

Project designers tried to include elements that connected naturally to particular calculus concepts. For example, population growth naturally associates with differential equations. But more importantly they tried to make the project connect to students' own majors such as biology. The project designers discussed how they had to think about what calculus topics students needed to know and how the project could help them with difficult concepts. One project designer explained that conceptually, integration is difficult for students, and so he wanted the project to connect integration to a real life problem. They are interested in making the topics current such as using calculus to study greenhouse gasses. By putting more emphasis on a meaningful situation, students would naturally move away from a more mechanical view of calculus.

Several tutors viewed the project as motivating interest in math. Previously their math classes involved memorization and refinement of processes. As embedded tutors they appreciated a mathematically relevant context.

One said, "I think that it was really interesting getting to do lots of different things, but I also think that it is something that students talk about especially within the same degree program. So if we did something that was more biological, population based... one semester when I had a classmate who did something that was more ecological, like the oil spill one, we could have those conversations about how we're applying the same skills in a very sort of different context."

It is evident that tutors and creators think a lot about the students. They care about whether the project is feasible and relevant to student interests. The majority of the students in Calculus II are science majors, so project designers looked for projects that related to biology and chemistry, as we do not offer a physics major at our institution. Typically, projects are related to an important social issue (e.g. climate change and overpopulation). Several tutors expressed empathy for the students and were motivated to help students practice, find related problems in the homework, and discover new ways to explain things.

Tutors took advantage of their unique relationship with the students. Tutors know what the students are hearing from the instructor; they can fill in gaps from the instructor to the students and can also give some of the students' perspective back to the instructor. This advocacy for the students helps the instructor better understand the needs of the students. The tutor's view is different from the instructor's; their recent mastery of the material helps them to understand the students' thought processes. Students often felt more comfortable talking to a peer.

One tutor had designed the project that was being used that semester. This experience was especially fruitful, as they had thought very deeply about what they wanted to include in the project, how students learn, and where they were lacking in skills. They reported that this greatly increased their effectiveness as a tutor for the course; this self-reporting is consistent with our observation.

## THEME B: INSIGHT INTO APPLYING MATHEMATICS/CALCULUS

Our main motivation for incorporating projects in Calculus II is to give all students the ability to talk about calculus and its uses. The project challenges students to think about the mathematical concepts in a contextualized

situation that requires imagination and technological assistance. Our tutors and designers reflected about their time as calculus students, both here and elsewhere, in their interviews. Calculus II students must communicate among themselves about mathematical modeling in order to successfully complete the project. Many cited this communication as crucial.

One described group work in their previous calculus class at a different school: "It was never actually going out into the world and presenting your findings and being knowledgeable of what you were talking about, so I liked that as a component." One said their experience as a Calculus II student here helped them talk to professionals at a job fair.

The project designers' reflections deepened when discussing the thinking that went into designing a project. Project designers looked for ideas that were feasible for Calculus II students to complete in a semester. Designers wanted their projects to be socially relevant and therefore searched for an interesting area and then had to deconstruct it; one chose to study head injuries and came across the head injury index. That led to a new kind of analysis for her, working backwards from a formula to work out its derivation. The designers intended for students to experience how a model may be limited, but they still wanted students to make valid inferences about what formulas would be reasonable to try. One designer noted his own growth as a student through understanding why concepts are true rather than simply accepting them as an established principle.

The project designers applied knowledge acquired since having had Calculus II. One, an actuarial science major, designed a project using mortality tables. Reflecting on the project done and the project design led to the problem of data. The projects needed some publicly available data to analyze. They could see that the data used when doing the project as a Calculus II student had problems. Most of the designers expressed awareness of the difficulty of doing a project with real data, in particular, finding a good source and dealing with flaws in the data themselves.

There is consensus among the designers that the project brings value to the class. It gives insight into how calculus can be applied in the real world, and the learning

that is needed to navigate the project provides an incentive for students to learn more about calculus itself.

### THEME C: FEEDBACK ON IMPROVING THE EXPERIENCE OF EMBEDDED TUTORS AND RESEARCHERS

Tutors and researchers gave feedback on how to run the different activities. The tutors felt strongly that more preparation and better coordination between instructors and tutors was needed. They gave suggestions about the structure of the class and insights on the value they should bring to it. Tellingly, the project designers did not express concerns about what was expected of them. Their biggest concern regarded the difficulties of finding good projects, particularly those with usable data sets. Because the designers met regularly with their research mentor, they remained informed of the goals and expectations of the project.

Most tutors saw the value and importance of integrating technology into the class, but most did not feel that their skill level improved while tutoring. Many pointed out the need for more training for students, tutors, and instructors. The tutors believe that students in the class need more formal instruction on using the software, noting that much class time is spent troubleshooting the difficulties students are having or getting them started. The tutors felt that more training for them would improve their effectiveness, as they were unable to answer some questions students had. Finally, there are indications that the instructors also need additional training, both on the software being used and on the way to utilize the tutors effectively. In some cases the instructor relied on the tutor to troubleshoot any problems arising with the software. Most tutors felt instructors only explicitly engaged them when technology was being used in that day's class. In fact, many of the tutors were not active during class unless there was an activity involving computers.

It is not surprising then that communication was the most cited concern among tutors. Several of them said they wished they knew more about the instructor's goals. The true value of the embedded tutor is to act as a partner of the instructor, and for this he/she needs to be aware of what the instructor is trying to accomplish. Some tutors tended to hold back and not be proactive about helping, in part because they had no direction and in part because of their own inexperience and lack of training.

Many noted the value of having the time structured so that tutors are available to students both in and outside of class. Opportunities to be active in the class were important to the tutors, though some needed more prompting from the instructor. This suggests that some changes in the structure would help facilitate the tutor's activities. Possibilities include more training involving all members of the team, regular meetings between tutor and instructor where plans for the class are discussed, and a set of prompts for the instructor to help guide the tutor.

## Conclusions

Our experiences with student researchers mirrored those of others, even though our student research had a curricular focus instead of a mathematical one. In Seymour et al. (2004), a survey of seventy-six student science researchers at four different liberal arts institutions was compared with literature from fifty-four different papers on hypothesized benefits of being a student researcher.

They found that students reported gains in many areas, including confidence in their ability to do research, finding connections between and within science, their organizational and computer skills, their enthusiasm, enhanced resumes, and their attitudes towards learning and working as a researcher. In our study, we also found these gains, giving evidence that this type of student research project has many of the benefits of a traditional research project.

The main advantage of research with a curricular focus is the possibility for students to work when they are just beyond the calculus level. In our study, designers and tutors gained a deeper knowledge of how to apply mathematics and use technology. Both reflected on what makes a good teacher, indicating this type of experience could greatly benefit undergraduates who are interested in teaching. They also provided thoughtful comments on how to improve the program, most notably the need for consistent communication between tutors and instructors.

### 4.1 Best Practices for Incorporating Students in Curricular Design

Given the extensive amount of research on embedded tutors, we will concentrate primarily on best practices for student researchers.



- Meet student researchers and tutors at least weekly.
- Be available for tech support, orienting all students to new software.
- Pay students using timesheets rather than lump sums.
- Encourage researchers to become embedded tutors for the course (both before and after creating a project).
- Have a set of background literature, including previously used projects, available for new student researchers.
- Don't be too prescriptive. Let them brainstorm ideas and act as a sounding board for them.
- Have at least two students working at the same time; they can give feedback to each other, and bounce ideas off each other.
- Communicate your expectations to help them steadily progress.
- Use file sharing (Dropbox, iCloud, etc.) to prevent the loss of student work.
- Proofread and give feedback on projects and talks. Be supportive and encouraging.
- Make students aware of speaking opportunities (with enough time to write an abstract, to plan a trip, etc.).
- Provide internal venues where they can present their work.
- If the topic gets too deep for calculus allow it to become a more traditional research project.

### Recommendations for Further Study

We would love to see a quantitative study on our style of design process. For this, a large university or community college would have to undertake these activities in Calculus II or a similar course. We are also interested in more studies on the impact of doing research early on in college. In our specific work, it would be interesting to increase interactions between the embedded tutors and the project designers. It would also be interesting to have new project designers formally review old projects. This would structure their introduction to the design process and help them to think critically about issues involved in the design. Similarly, when possible, one could have the tutors formally review the current semester's project in the week prior to the semester as a form of tutor training.

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## APPENDIX A: INTERVIEW QUESTIONS

- + Describe your experiences as a student in Calculus II.
- + (Designer only) How did you go about creating the Calculus II project?
- + (Designer only) What did you learn while creating a Calculus II project?
- + (Tutor only) What did you do as an embedded tutor?
- + (Tutor only) What did you learn as an embedded tutor for Calculus II?
- + What do you think an embedded tutor should do?
- + If you could travel back in time, what advice would you give to yourself?
- + What resources would be useful for you to have?

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## APPENDIX B: CODING CATEGORIES

- Teaching style of instructors: (1) How it influenced you when you took calculus, (2) Learning in class you were taking, (3) Teaching style of instructor in the class you were taking, (4) Teaching style of instructor in the class you were tutoring.
- Teaching style of self: (1) Your learning due to your acting as a tutor, (2) Student learning due to your tutoring, (3) Communicating with students you were tutoring, (4) Project creation: reflecting about how to help other students.
- Resources: (1) Communicating with faculty, (2) Resources (computer-based), (3) Resources (other), (4) "People creating/tutoring should have property X," (5) "I needed knowledge about X," (6) "I used X to do Y."
- Uses of calculus: (1) Uses of calculus (class you were taking), (2) Uses of calculus (class you were tutoring), (3) Uses of calculus (project you created).
- Self-reported changes: (1) In how you think about calculus "I created a project, and now I am awesome at calculus," (2) Interest in mathematics/applications/teaching, (3) Communicating with an outside audience, (4) "I can do X."



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## APPENDIX C: SURVEY QUESTIONS

**When did you master calculus? (Select all that apply.)**

- + As a student in calculus class.
- + As a tutor.
- + While creating a new project (as my research).
- + In Calculus III.
- + In more advanced math or actuarial science courses.
- + In my job.
- + Other:

**What background should a student have before working on designing a new project? (Select all that apply.)**

- + Calculus II.
- + Calculus III.
- + More advanced mathematics courses.
- + A mathematical computing course.
- + A programming course.
- + Other:

**What software have you used? (Select all that apply from Maple or Mathematica, Wolfram Alpha, Excel, PowerPoint, Statistical software [specify type], Other.)**

- + At Roosevelt University outside of Calculus II?
- + At Roosevelt University while taking or tutoring Calculus II?
- + At your job, if you are employed outside of Roosevelt University?
- + What software do you think is useful for Calculus II students to learn?

**Ignoring exam days, about how frequently should a Calculus II class involve the following? (For each option below, select from Never, Once or twice, Monthly, Weekly, Every day.)**

- + A lecture.
- + Group work.
- + Project work.
- + Computer work.
- + Problem sessions.

**How do projects benefit Calculus II students? (For each option below, select from Essential for the students, Helpful for the students, Somewhat helpful for the students, They'd learn this without the projects.)**

- + Increased computational skills (taking integrals, etc.).
- + Increased conceptual skills (what does an integral represent, etc.).
- + Finding out that calculus is actually useful.
- + Increased skills working with data.
- + Increased skills working with people.
- + Increased skills with computers.
- + Learning about connections to other fields.
- + Greater ability to communicate mathematics.

**If you created a project, how did constructing a project benefit you? (For each option below, select from Essential for the students, Helpful for me, Somewhat helpful for me, Did not help me/does not apply.)**

- + Increased computational skills (taking integrals, etc).
- + Increased conceptual skills (what does an integral represent, etc).
- + Finding out that calculus is actually useful.
- + Working with data.
- + Working with people.
- + Working with computers.
- + Learning about a field you are interested in.
- + Increased patience.
- + Understanding how people think and learn.
- + Understanding how you think and learn.
- + Better research habits.
- + More experience doing literature searches.
- + More responsibility.

**What skills should an ideal embedded tutor have? (For each option below, select from Essential, Good to have, Not needed.)**

- + Strong mathematical content knowledge.
- + Knowledge of computer software.
- + Love of mathematics.
- + Desire to teach.
- + Enthusiasm.

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## APPENDIX C: SURVEY QUESTIONS (CONTINUED)

**What should an ideal embedded tutor do? (For each option below, select from Essential, Good to have, Not needed.)**

- + Act as a bridge between faculty and students.
- + Help with project during class.
- + Help with calculus examples during class.
- + Help outside of class.
- + Make connections between the project and the class.
- + Help build student confidence.
- + Meet regularly with faculty outside of class.

**Which skills increased for you due to your work as an embedded tutor or project designer? (Select all that apply.)**

- + Presenting posters.
- + Giving talks.
- + Writing papers/projects.
- + Tutoring.
- + Confidence in my ability to do math.
- + Confidence in my ability to explain math.
- + Other:

**What resources are needed for embedded tutors? (For each option below, select from Essential to have, Helpful to have, Somewhat helpful to have, Not needed/not applicable.)**

- + MyMathLab Course Access.
- + Tutoring time in 401/Math and Science Resource Center.
- + A room dedicated to only tutoring (not classes).
- + Regular communication with faculty teaching the course.
- + Tutor orientation and training prior to the start of the semester.
- + Computer orientation and training.
- + Written sample solutions for homework assignments.
- + Written sample solutions to project parts.
- + Ability to schedule office hours each week at times that are convenient for both you and students (not necessarily fixed).
- + Feedback on performance.

**If you would like to clarify or expand on any of your answers, please do so below.**