

Virtual Service-Learning Tutoring Experience for Engineering Undergraduates

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Abstract

In the fall semester 2020 a service-learning option was provided to students enrolled in a probability and statistics class that is required of all engineering majors. The instructor had previously participated in service-learning seminars for faculty at the university who were interested in using that pedagogy in their classes. This paper reviews the seminar program, the background of the community partner, the nature of the service-learning experience and the qualitative reflections of the students who participated in the on-line service experience. Half the class chose the service option and half chose to program a simulation. The service-learning option involved tutoring middle school and high school students in math, responding to four writing prompts or reflections, and a project. The project entailed the undergraduates creating their own lesson and activity about probability which was offered to the entire tutoring community. Each tutor first presented a brief lesson about a statistics topic such as combinations, dice, cards, and other topics typical early on in a probability course. The undergraduate tutors created a game board with categories drawn from the brief lessons they offered immediately prior to the game. Every correct answer was awarded a point and the student with the highest total won a small prize. The community partner was pleased with the experience as was the instructor and the students who participated. It is anticipated that it will be repeated in the fall of 2021, perhaps in an in-person format. The learning objectives for the course as well as the community needs, were at least partially met. The undergraduate students who participated in the service-learning option gained perspective on their own mathematical thinking and learning. In conclusion, service-learning as an option is an attractive pedagogical tool to put into the mix of one's courses.

Service-learning general definition and background

Service-learning is a pedagogical approach that can be successfully applied to engineering education. There is the pioneering example of engineering projects in community service (EPICS) which comes from Purdue University [1]. EPICS programs aimed to provide their community with technical expertise that they might not have themselves or have access to. This allows the community organization an opportunity to achieve some of their goals. On the other side, the service-learning experience can expand and broaden the experience and thinking of students, in this case, undergraduate engineering students. This author's own understanding of an ideal for service learning is that it meets the learning aims of a course and the students in that course by allowing them to engage their learning in 'real life' and thereby a more complex and nuanced environment. At the same time, it must meet community needs. This one axis for service-learning is to meet both the needs of the community and the pedagogical needs for the course. One way to understand the types of community engagement that are possible is to consider an axis of project-based service and ongoing service. All of this is distinct from one-time service opportunities, which although enriching separately and in a course context, is not

the same as service-learning. This project ultimately incorporated both strengthening an ongoing service relationship between the community partner and the university and have a single project focused event for the students that was also more clearly focused on course context.

Service-learning program at Loyola University Maryland

Loyola University Maryland has a long and distinguished history in community engagement. This has resulted in some enduring and long-term partnerships with the community. Many of these partnerships have naturally evolved around the need for educational resources, specifically tutoring, in the K-12 environment. The nature of the undergraduate population at the institution and their majors has made initiating and establishing service-learning in the STEM fields more of a challenge. There are examples from biology, chemistry, and health related fields, but partnerships around engineering, math, and physics are rarer at the institution. One of the difficulties is finding either a single project or an on-going service that can be at the appropriate level and topical content for an undergraduate engineering or math course. Successful examples abound and the Michigan Journal for Service-Learning as well as the Journal for International Service Learning in Engineering are both excellent resources. There have been series volumes and books dedicated to the topic of service-learning in engineering [1] [2] [3]. However, applying them to one's institution and location may still prove to be a challenge. In addition, as outlined below, there are several choices that one can make in creating a service-learning pedagogy for the classroom. The initial work in service pedagogies in STEM were probably more oriented towards one time project or service opportunities. This project has elements of on-going service with a long-established community partner as well as establishing a one-time project or event. The author wanted to look more deeply at these questions and see if a pilot program might be possible.

Service-learning faculty fellows program

After participating in service-learning workshops and programming on campus as well as being a member of the advisory committee for community engagement and service, the author officially participated in the service-learning faculty fellows program in the spring of 2018. Bringing service-learning into the STEM classroom was an important goal for the author. The parameters for what that might look like in practice evolved during the spring workshop and work with its facilitators. The ideal scenario was conceived to utilize service-learning in a Probability and Statistics course. This course is required of all Engineering majors and is cross listed with the Mathematical Sciences department. The elements that the author wanted to see in a service-learning experience included the following:

- Math that explicitly included course content
- That the experience explored 'non-technical' or social structural issues and perhaps engage the community more broadly and make the students think more broadly and integrate their thinking about STEM in a social context

- Service-learning as an option for students, not a requirement, and therefore equivalent to other course expectations. It could not take away something vital from students who either were or were not in the service-learning option.
- Ensuring that the service-learning experience met real community needs and was acceptable to the community organization.
- Mutual expectations among the instructor, community partner, and students were established and understood.

Probability and Statistics Course

The probability and statistics course, as many such courses are organized, starts with units on counting probability. That is, topics include counting of all outcomes in a defined sample space and then the number of those outcomes that meet the described criteria to answer the question of “what is the probability”? Students often find converting word problems to a correct understanding of the counting of outcomes difficult and counter intuitive. The errors involve either understanding the full size of the sample space or else counting the number of cases that meet the criteria. This is particularly true when conditional probabilities are introduced. The author wanted to provide more opportunity for students to think about these questions than can be afforded in a traditional semester long lecture-based course.

Programming assignment

The first element of a project-based assignment for the course was started a few years prior when a programming assignment was introduced in the course. The assignment was for students, in teams, to program a simulation of a well-known problem and to compare the results of the simulation with a closed form theoretical calculation of probabilities. The two problems that were most often chosen over the years were the so-called “Monty Hall Problem” and the “Key Problem”. The Monty Hall problem is based on the game show Let’s Make a Deal, sometimes the host, Monty Hall, would offer a contestant a chance to switch their choice of ‘door’ where it would be revealed whether they won the prize. He would do this after opening a different door to show that it contained no prize. The question is, what is the best game strategy to stay with the original choice or to switch. It is surprising that this simple question has engendered so much controversy. The correct result and strategy (switch) can be shown theoretically with the use of conditional probabilities [4]. The Key Problem asks the question about what the best position is to play a simple game. The first participant picks one of four keys, only one of which will get them possession of a new car. Is it best to be the first participant, second, third or fourth? This is a problem of probability *without replacement* of the key once tried.

Both problems can be solved theoretical with the careful application of conditional probabilities, but both often have results that are counter-intuitive for most people. It was hoped that by programming a Monte Carlo simulation of the problem, they could develop their intuition. A Monte Carlo simulation just means a computer program which builds a probability distribution

by repeated iteration of the program [5]. They could use the programming language and random number generator of their choice. One observation of the author's was that students focused on the mechanics of programming the simulation rather than understanding the theoretical proofs or developing an appreciation of the results of simulation. Even as the course was required of all engineering majors, there were those students who wanted and could benefit from a different kind of experience.

Service-learning assignment introduced Fall 2020

Despite the restrictions of the pandemic situation that meant that there would be no in person contact, the university, community partner and faculty member were able to arrange over the Spring and Summer of 2020 to introduce a service-learning option into the probability course. Now students would have the option of doing a simulation or engaging in service-learning. One part of the service would fulfill the community partner's clear and expressed needs for tutoring in mathematics. There were many undergraduates ready and willing to work with younger students as tutors in their social science and humanities related courses, far fewer were comfortable tutoring mathematics. The service partner has students who participate in their programs from middle school through high school and includes students who are taking or will take regular or advanced mathematics at the high school level. That is the undergraduate tutors would be challenged in their own understanding and communication of mathematical topics that could include algebra, geometry, trigonometry, and analytic geometry. Although some of the students might need review, skill practice and remediation around earlier topics, there would be challenging math involved.

Community partner background:

Bridges is a non-profit organization that was founded in 1993. The organization offers support to students from middle school into college. Currently 296 students are involved in this initiative entering the program from eight public schools in the Baltimore city area. 188 volunteers are involved in the year-round programming. Students receive support year-round through tutoring, career exploration and counseling, college admission guidance, leadership development, SAT/ACT test preparation, and mentoring. Volunteers from multiple schools with a wide range of knowledge in many subjects accommodate the needs of the students at any point in their educational career.

Over the spring and summer of 2020, the organization shifted to a remote learning format and handed out materials tailored to each student's needs. Supplies such as paper, pencils, books, math exercises, and art materials were distributed. Other technological, food and family system supports and needs were also addressed as feasible. The organization developed experience with protocols in remote tutoring, which was most important when the undergraduate tutors were engaged. Specifically, supervision in breakout rooms, training in working with minors and policies and procedures to meet safety and legal requirements were generously offered and

borrowed from what the organization had already established. The author found that having a model for this kind of detail was invaluable in making their personal experience of service-learning as easy as possible. Having an experienced partner and established relations with an office of community engagement allowed the faculty member to focus on the pedagogical elements rather than logistics. One advantage to the virtual format is also that it lessened the usual logistical problems of timing and transportation, which can be complicated in after school programs for minors. The virtual environment has proven that it can be flexible and welcoming for all participants and may even allow some involvement what was not possible when in person tutoring created time and logistical constraints.

Virtual service

Students were assigned to one to two hours per week of virtual math tutoring. The ordinary expectation for service-learning is for twenty hours of service in a semester. Because of the pandemic and virtual nature of all the activity the expectation was more flexible with a minimum expectation of ten hours total. All of the students who engaged in this project exceeded that minimum. The tutors were engaged with math at a variety of levels from middle through high school. Students were placed based on their comfort and experience. The response from the community partner was extremely enthusiastic as the demand for tutors comfortable with math far exceeds the supply of those willing and able to do the work. The community partner is eager for any student to volunteer without any necessary connection to a course or that course's content and learning aims. The undergraduate students who volunteered for service generally said they did so because it was connected to a course and 'for credit' and that they preferred the idea of service to the idea of the alternative (the programming project). An attempt was made to keep the workload for both options equivalent. In addition to the service, the students provided answers to some writing prompts, as described later, and worked as a group to create a project or experience for the learning community at the partner site. That was a one-time event that the group created on their own to teach some probability theory and then provide a fun game to reinforce that learning. This was the 'probability jeopardy' event.

Probability Jeopardy

The event was planned completely by the students engaged with the service-learning option. The community partner provided some guidance from their experience about what would be engaging to their students and were also able to provide money for a small prize. The author had initially thought to engage parents and others in the event that would perhaps be longer and over multiple days and would include discussion of the idea of expected value and how that impacts people's everyday understanding of decisions they make, such as buying a Lottery Ticket. Bringing the math, sociology, and politics of the lottery was an initial thought, but the perhaps more modest effort was completely driven by the undergraduates and was well received by the participants. The event lasted for about 90 minutes. The probability and statistics students

present four areas of probability, including basic probability of cards and dice as well as combinations and permutations. They then created two ‘Jeopardy boards’ that had questions of increasing difficulty about the various probability topics. The students who had been tutored and other mentors in the program all participated. There was the standard Jeopardy musical countdown and then everyone participating provided answers in the online chat. Anyone who had the correct answer received a point and the person with the highest score won the small prize. The participants ranged from a middle school student to adult mentors. The author observed the following about the event: some of the questions were difficult enough to challenge the adults, the high school participants were very engaged and were clearly very mathematically talented. One student had excellent intuition about the right answers even if they did not have the theoretical background. Another participant, who was in middle school, expressed a range of emotions about the event and its difficulty for them. They continued talking about the virtual event to the participants even as they were leaving their location to travel home. They expressed both frustration and excitement, what the author might describe as that itch a young person gets when seeing something a bit beyond their current capability, but they are eager to achieve.

Outcomes

As a qualitative means of assessing the outcomes of the service-learning program, the students who participated in the program were asked to write reflections in answer to three prompts. The first prompt asked the tutors to “**reflect on your own math skills and problem-solving approaches. Reflect on the techniques that were successful to teach/tutor math.**”

One participant, who I will focus on and call L., starts by noting,

“over the past few tutoring sessions, I’ve worked with a wonderful middle school student who needs assistance with her algebra class. I’ve helped her relearn some ideas and work on the skills that she already has. She comes to our sessions excited and ready to learn along with the material that she wants me to help her with that day. I was nervous about tutoring in upper-level mathematics like calculus because I wasn’t sure about how much I would remember. I am confident in my ability to tutor in algebra and can thoroughly explain ideas for her to better understand.”

She then goes on to make a useful specific comment about teaching in the virtual environment when she notes,

“one of the many things that has been a helpful resource, especially with remote tutoring, is using the whiteboard feature on Zoom. I’m able to write out short problems and expressions for her to visualize what I’m talking about and for her to work with me on it. There are multiple times that I ask her to complete an expression to show that she has retained the material and skills that I covered with her.

...There was a time this past week that I struggled with explaining a concept with dividing mixed fractions, and I was upset that I couldn't help as much as I wanted to. When I am able to explain concepts and really break the tips and tricks into her mind, I can tell. I ask her to complete a problem on her own and I ask her to tell me her "plan of action" and I help guide her through it. When she gets to the answer by herself, I am so proud of her! We do a little celebration and I let her know that she did a great job. She also gets excited and giggles a little. This little interaction makes everything all worth it."

The next writing prompt was geared towards the specifics of the probability course and asked to **Reflect on one important take-away from thinking and teaching about games of chance and expected value.** L. notes,

"...it was interesting to think about the basic concepts of statistics and how they are the primary level of the subject. The topics that we are learning about now have the same concept as the most basic ones but applied in a more sophisticated and complex way. I think it was important to realize how everything is tied together and how there are steps and building blocks in our learning.

For example, the use of the mean value of data. I can recall in third grade I started to learn about the mean, median and mode values. I expected to use the different values down the line in my math career but expected the upper-level statistics work to be a big variant of basic math skills. In reality, the work that we began doing still incorporated those basic concepts, like the mean, but at a more difficult level and at different points in a calculation. This idea of knowing the basics strongly relates to the importance of math education at all ages. It's important to focus on the basics and take the time to be proficient sooner rather than later.

... Statistics is one of the big overarching mathematical ideas that can be seen in a lot of aspects of life. The probability of winning a game, the probability of picking a certain card, or even analyzing data collected in testing materials in the engineering world, there are countless ways to practice these concepts every day.

...It occurred to me that the students that I was tutoring didn't have an appreciation and a fascination with numbers like I do, so making the jeopardy game was a fun way to get them to enjoy math and see it in a different light. Incorporating math skills and teaching them about chance and expected value showed them how to see it in the real world and realize that math is everywhere."

Finally, the students were to **reflect on the value of math skills for you and for the students you tutor. What does a good math education allow or provide? What happens if you don't get that opportunity? Refer to the work of Bob Moses and the Algebra Project.** [6]

To this prompt L. writes,

"I think learning different math skills and taking part in a math education is important because it's such a universal language. The amount of math used in everyday life is

completely disguised to the overall population. I hear people say all the time how excited they'll be to not have to take another math course or not have to do math ever again, but in reality, they use it every day. Bob Moses, the founder and president of the Algebra Project, explains how math education is the tool for organization. The Algebra Project is meant to change the platform from when people would speak and others would listen to a more engaged environment having students participate more in problem solving. The elementary math education was based off the regimentation of language that no one really understood. Students were simply being taught to memorize and not actually apply concepts. This project allowed for the changing of the math education which taught students the problem-solving skills that they need."

"... What I learned most while tutoring is that the grade level of the students doesn't matter, every student is at a different point in their math education. It was clear to me that some students weren't as strong in their math skills as they were expected to be because their teacher didn't take the time to teach them the basics. They were put at a disadvantage when later in their math careers they start to struggle with the most basic concepts that they should already know.

I gained a greater appreciation for my past introduction to math and dedication of my teachers because it showed me how to love numbers. I am grateful for my education system on granting me the proper skills to strive in the STEM field, and I think it's important for everyone to be able to use math and have an appreciation for how it plays a role in our everyday lives."

Conclusion

Other work also shows ways in which service-learning experiences have a powerful impact on students' attitudes [7]. The author reviewed their aims for this project, the event project executed by the undergraduates, their written reflections and end of class discussions. The following was achieved:

- Community needs for math tutoring, including at a relatively high level, were met. A collaboration between the author and the nonprofit organization was successful and has every expectation to continue whenever the probability and statistics course is offered. There is still the great need for general ongoing math tutoring that this does not address.
- The student tutors enjoyed the alternative to the programming project, while there still were students who chose, enjoyed, and learned from the programming option as well. Keeping both in the course would seem to be important.
- Students were able to reflect, to some degree, on their own learning, teaching techniques and the larger social implication and context around access to quality STEM education. This should be assessed more robustly in the future.
- Students were able to generate and execute a project that related closely to course content and helped them learn that content at a deeper level, as expressed in their own self-reflections. The author initially had more elaborate goals to engage in conversation that

might shift broad community perspectives about mathematics. It is still an open question whether a more elaborate project with more ambitious goals is feasible in this format or even desirable in the context of service-learning for a probability and statistics course.

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