Robotics service learning for improving learning outcomes and increasing community engagement

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Abstract

Service Learning (SL) is a teaching and learning strategy that integrates meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities. Students in a technical elective robotics class in the Mechanical Engineering Department at the University of Texas at San Antonio (UTSA) opted for either a final project or service learning for 25% of their grade. For SL, the students had to work with elementary and middle-school children in San Antonio over a period of 10 weeks to mentor them on building and programming robots with LEGO® Mindstorms® for the FIRST® LEGO® League tournament. In parallel, the undergraduates also learnt LEGO® Mindstorms in the class by creating robots for assigned labs. This way they were able to apply concepts taught in the class towards community service. As part of the service learning option, the students completed self- reflection journal entries before-, middle-, and end-of the program. For assessing the SL, the undergraduate students were administered a survey at the end of the program. The self-reflection journal entries indicated that the main challenge faced by the students was their self-doubt about their ability to teach robotic and engineering concepts and to sustain the attention of the children. The surveys indicated that the students felt SL motivated them to learn and improve understanding of the course material. Students also felt that there should be more SL options in the Engineering curriculum. Finally, an analysis of students' grades in the course indicated that those who selected the SL option scored one grade higher than students who did the final project option. Our conclusion is that SL is a promising approach to improve students learning outcomes while benefitting the community.

Keywords

Service Learning, Robotics, LEGO® Mindstorms®, Hispanics, STEM.

1. Introduction

A recent Science, Technology, Engineering, and Math (STEM) factsheet [1] posted by the US Department of Education through a White House Initiative on Educational Excellence for Hispanics highlights that although 20% of the US youth population is Hispanic, only 7% of STEM degrees are awarded to Hispanics, and only 2% of the STEM workforce is Hispanic. The fact that Hispanics are profoundly underrepresented in STEM coupled with the fact that they are the fastest growing population in the country --- projected to make up 29% of the entire US population by 2050 [2] --- highlights a pressing need to excite Hispanic youth to pursue STEM careers. This paper reports on our attempt to address this need by creating a service learning

module within an existing Robotics course in the Mechanical Engineering Department at the University of Texas at San Antonio (UTSA). Specifically, students in the Robotics class mentoring children in elementary- and middle-schools with a high Hispanic population (greater than 90%) to help them prepare for the FIRST® LEGO® League tournament.

Service Learning (SL) is a teaching and learning strategy that integrates meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities. SL is more than volunteering because it has a curriculum associated with it. SL is not an internship because it is designed to meet specific community needs [3]. In the robotics course at UTSA, a part of the curriculum are the labs in which students use LEGO® Mindstorms® to solve and/or simulate real-world problems (e.g., parallel parking, localization, line following). The community need is to mentor school children at building and programming LEGO® Mindstroms® in preparation for the FIRST® LEGO® League tournaments. The need is genuine because: (1) some of the school teachers have little experience with building and programming robots; and (2) the teacher needs help mentoring the group of children (typical size is 20).

Our literature review related to Service Learning (SL) indicates promising outcomes for engineering students. Salzman and Strobel [4] taught a SL course at Purdue University in which undergraduate students mentored high school student teams participating in the FIRST® Robotics contest. They used surveys and interviews to determine why undergraduate students chose SL. They found that the prime reasons are: being able to stay connected to the FIRST® Robotics Competition after high school, the ability to develop communication and leadership skills, the close relationships that they developed with the high school students, and the opportunity to contribute positively to both the local and FIRST® Robotics communities. Sevier et al. [5] taught the Introduction to Engineering course at Boise University and Michigan University of Science and Technology in which the student either chose an assigned project with clear technical specification or choose a community project where they were given the problem and had to come up with their own solution. They called the former the non-service learning component and the latter as the service learning component. They found that students who did service learning had a higher motivation and also showed better ABET outcomes. Schuetze et al. [6] also found in their qualitative study at the University of Texas at San Antonio the reciprocal learning benefits for undergraduate students mentoring Hispanic students in preparation for FIRST® Robotics competitions. They concluded that robotics clubs nurture aspirational and self-efficacy on all participating members of the learning environment. Specifically, they found that protégés and mentors expressed a better understanding and an increase in STEM knowledge as well as affirmation towards STEM education and careers goals.

In this paper, we present some of our experiences and findings from incorporating a SL component to an existing robotics course at UTSA (Section 2). Then we present the analysis to see if SL improved students learning outcomes by comparing it with the other group, who did the project learning component (Section 3.1). Then we analyze service learning in detail through analysis of student written reflections (Section 3.2) and end of semester survey (Section 3.3). Finally, we discuss the results and make some suggestions (Section 4).

2. Background

The Academy for Teacher Excellence (ATE) in the College of Education and Human Development created an after-school informal learning club platform for low-income, high need elementary- and middle-schools funded by a US Department of Education grant. In this program, an Education Specialist from ATE sponsor K-8 teams in order to stimulate interest in STEM-related fields, develop 21st-century learning skills, and allow students to participate in the FIRST® LEGO® League tournaments. To this end, ATE provides LEGO® sets, FIRST® LEGO® League registration and competition fees, training and support for the campus teachers, and recruits and trains undergraduate students from UTSA to mentor the children. Currently, ATE is mentoring 232 students in 12 schools [171 elementary; 61 middle school]. Table 1 gives the school demographics. There were 56% males and 44% females of which 70% were Hispanics, 7% non-Hispanics, and the rest 23% did not indicate their race.

School Name	Total	Male	Female	Hispanic	Non-Hispanic	No Answer
Briscoe	14	8	6	12	2	0
Crockett	13	11	2	12	1	0
Douglas	29	13	16	14	4	16
Highland	15	9	6	12	2	0
Hillcrest	23	10	13	15	2	6
Kriewald	12	8	4	9	2	1
Price	10	5	5	8	0	2
Regency	33	17	16	19	5	8
Woodlawn Hills	22	13	9	14	1	7
Total Elementary	171	94	77	115	19	40
Matthey MS	9	7	2	5	1	3
Whittier MS	27	15	12	22	0	5
Woodlawn Academy	25	15	10	20	0	5
Total Middle School	61	37	24	47	1	13
Grand Total	232	131	101	162	20	53

Table 1: Demographics for the elementary- and middle-school students.

Most service learning (SL) at the University of Texas at San Antonio (UTSA) is overseen by the Center for Civic Engagement. From 2014-16 there were 225 service learning courses offered, however none of these courses were in the College of Engineering. The authors created the a pilot Engineering service learning course by incorporating a module within an existing Robotics course at UTSA and partnering with the Academy for Teacher Excellence in the College of Education and Human Development.

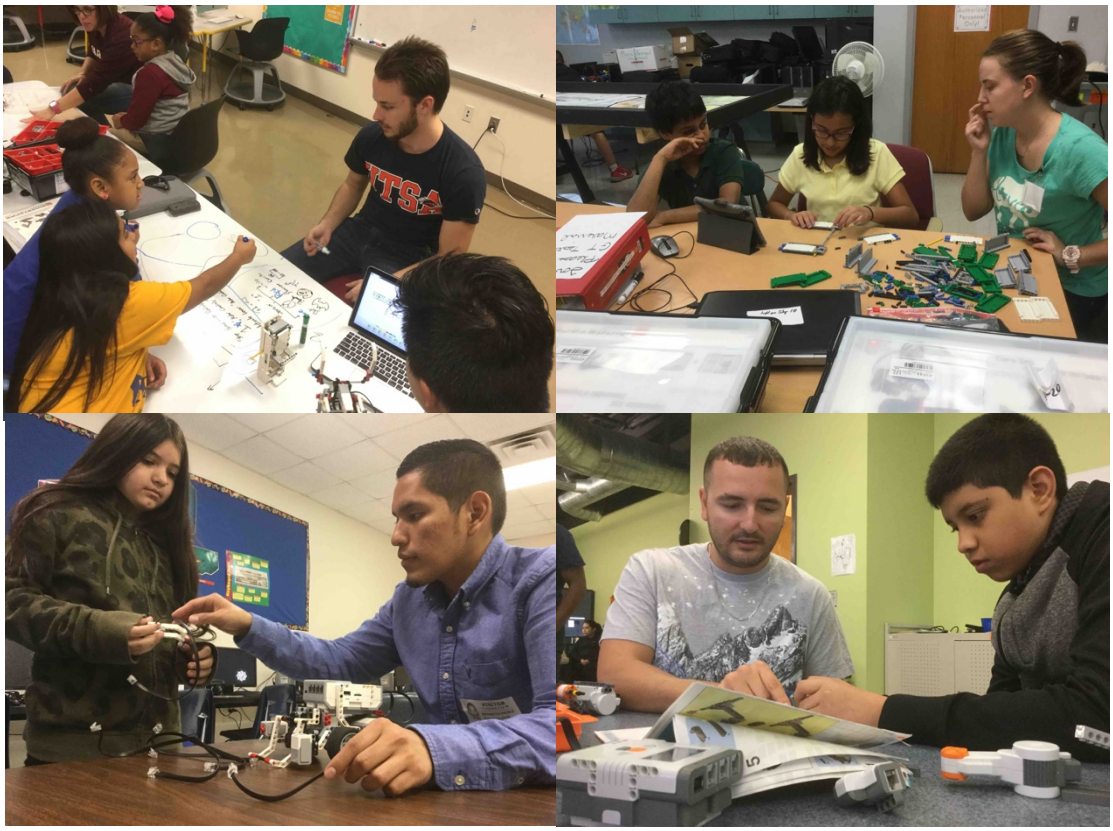

Figure 1: Undergraduate students working with elementary- and middle-school children.

Fundamentals of Robotics (ME4773) is a senior-level technical elective offered in the Department of Mechanical Engineering at UTSA. In this class, students primarily learn about kinematics, dynamics, control, and planning of manipulators and mobile systems. Students are also expected to do programming and implementation of taught concepts through MATLAB simulation and LEGO®-based hardware labs. Each week students are assigned a homework and/or lab. This semester there were 8 homework assignments and 4 labs. Students were assessed based on their grade in the homework, lab, midterm, finals, and service learning or a final project. The service learning/project accounted for 25% of their course credit.

In the Fall 2016 semester, 33 of the 52 students chose to do service learning over the final project option. The SL involved mentoring elementary- and middle-school children in after-school robotics clubs. Undergraduates assisted the K-8 students with designing and building robots, thinking through the robot re-design process, help with programming using LEGO® Mindstorms® EV3® software, all in an effort to prepare young students for the FIRST® LEGO® League tournaments in the Spring. The undergraduates were expected to mentor at the campuses at least 10 hours or 10 visits (no more than 1 visit per week). Students had to write reflections at the start, mid-point, and end of their SL to help them ruminate over their experience. The students were provided with questions to guide the reflections. Students also completed a survey that helped the instructor to gauge the Service Learning experience. Each student who completed the required service learning hours were paid $50 towards gas mileage through an NSF grant.

Before the program started, the undergraduate students signed a waiver removing any University liability towards mishaps occurring due to the service learning (e.g., an accident). Also, the parents of the children in the elementary- and middle-schools signed a photo release form that allowed UTSA faculty and staff to take photos of the event.

The students learnt about building and programming robots using LEGO® Mindstorms® (the same kit used by the schools for FIRST® LEGO® League) as part of the course requirement. This was essential because it made the student comfortable with the robotics kits. The students did 4 labs: (1) introductory lab to learn how to use the sensors, motors, and program using LEGO®; (2) a localization lab where students program a car to drive around and estimate its position and orientation using differential drive kinematics; (3) a line following robot; and (4) parallel parking. These labs were harder than the actual technical sophistication needed to help the kids on the FIRST® LEGO® project.

3. Methods and results

3.1 Learning outcomes

A central question in this study is: Did service learning improve undergraduate students' learning? One way to do this is to compare the students' final grades between the experimental group who did the service learning and the control group who did the project. There were 13 undergraduate students who did the project while 32 did service learning. We removed the 7 graduate students in this analysis. The average grade of the experimental / project learning group was a C+ (course total 79/100) while that of the control group /service learning group was one grade up, a B (course total 83/100). However, note that students who did the service learning part of the course scored 1 points higher than the students who did the project learning. But even after taking this in account, the service learning students scored on average higher than the project learning students.

3.2 Tracking student progress

To track student progress, we used GivePulse, an online website that allows listing, finding, and measuring impact through community activities [7]. The software has been purchased by the University for tracking service learning activities by faculty/students of UTSA.

GivePulse was used by the students to keep a track of the hours they spent in the schools. At the end of the service learning, the 33 students had logged 314 visits and 404 hours. This amounts to 9.5 visits/student and 12 hours/student over the course of 10 weeks. Note that students were required to do 10 visits and/or 10 hours of service learning over the course of the semester.

3.3. Reflection questions

GivePulse was also used by the students for reflection entries. Students were asked reflection questions before-, mid-, end-of the program. The reflection entries counted 5% of the students course credit. The reflection questions were not anonymous. The questions are listed below followed by our analysis.

These refection questions were asked before the service learning program started.

R1. I am/am not excited about the idea of mentoring in an after-school robotics club this semester because... (Briefly explain why/why not)

R2. What do you think the most challenging aspect of being a club mentor will be? What do you think will be the easiest?

These reflection questions were asked at the mid-point of the service learning program

R3. So far has the mentoring experience met or challenged your expectations? In what ways?

R4. How many children at a time are you working with during club meetings and what is your role during club meetings? (Describe some of the things you are actively doing as a mentor)

R5. How are you able to apply the knowledge and skills from ME 4773 to these club activities?

These reflection questions were asked end of the service learning program

R6. What were the challenges that the young students in the robotics club faced, and what was your role in helping them overcome those challenges?

R7. In what way did the mentor role challenge you personally, and how did you overcome that?

R8. In what ways did this mentoring experience help you understand your strengths and/or weaknesses?

R9. In the beginning of the semester you answered a question about whether or not you were excited about mentoring/service learning? Has this perception changed and to what extent now that you are done with the service learning experience?

Next we present some general observations based on the students' reflections.

R1, R3 and R9 assess students change in attitude, if any, towards service learning. About half the students were excited about service learning and their attitude did not change. The rest were not sure about service learning when they started but all of them eventually liked the experience. These students expressed some of the following reasons: not sure what to expect, intimidating to teach/mentor, thought that it would be too much time commitment.

For R2 most students felt that the most challenging aspect would be to teach and get students to focus on the task at hand. Some also felt that balancing mentoring and course load would be challenging.

For R4 student worked anywhere between 2 to 20 children. These involved brainstorming, helping with programming, and answering questions as needed.

For R5 about three fourths of the group felt that the course and assigned labs helped them in service learning. The others noted that the programming in the schools was very elementary or that programming was not covered to a great extent and hence felt that the course and labs did not help much.

For R6 the main issues faced by the kids were a combination of getting focused, programming, and problem solving.

For R7 a few students found that mentoring was an easy experience, but a vast majority felt that communicating concepts in simple ways to the kids challenged them the most.

For R8 a vast majority of the students felt they they were surprised to see that they could communicate with the kids about abstract concepts in simple ways.

	Question	SA	A	N	D	SD	Mean	Dev.
1	Service learning helped to increase my motivation towards the course material.	21	55	18	6	0	3.91	0.79
2	Service learning helped to improve my understanding of the course material	15	58	21	3	3	3.79	0.84
3	The assigned LEGO labs helped me to mentor the young student participants.	55	30	15	0	0	4.4	0.73
4	The young student participants from schools need mentors	70	27	3	0	0	4.67	0.53
5	I enjoyed the mentoring experience	55	39	3	0	3	4.43	0.82
6	Service learning should be extended to other engineering courses where it is relevant	58	27	3	6	6	4.25	1.15
7	If I were to choose an option for this course again, I will choose service learning over a final project	70	24	3	0	3	4.58	0.81
8	If instead, there was an option between Service learning and MATLAB simulation and animation of robots, I would choose Service learning.	24	40	24	9	3	3.73	1.02

Table 2: The survey questions and response percentage of all 33 students who took the survey. The columns are: SA, Strongly Agree (5 points); A, Agree (4 points); N, Neutral (3 points); D, Disagree (2 points); SD, Strongly Disagree (1 point). The points are assigned to each option in order to compute a numeric mean, which is shown in the last column.

3.4. Survey

To assess the effectiveness of service learning we did a class survey using University purchased course management software Blackboard at the end of the semester, but before the final exams. The survey consisted of 8 multiple choice questions on a 5-point Likert scale and 3 essay type questions. The survey counted to 5% of their course credit. All 33 students registered for service learning took the survey.

Instructions to the students before taking the survey: This survey should only be taken if you participated in service learning. It carries 5% of your grade for the service learning part. It is confidential. That is, I get a list of people who did the survey but I don't know your responses. Please do the survey diligently. It will help me improve the course and it will also allow me to report the results to the funding agency (the National Science Foundation). Reporting will be done by submitting a paper to an education conference early next year. I thank you very much for your time and for choosing service learning. NOTE: You have to complete the survey in a single sitting. You cannot save the survey. The survey has 8 multiple choice questions and 3 essay time questions. It should not take more than 10 minutes.
The 8 questions and student response is shown in Table 2

3.2.1 Multiple choice questions: Q1 through Q8.

Questions 1 and 2: Questions assessing motivation and learning in the course.
Q1. Service learning helped to increase my motivation towards the course material. Mean 3.91/5.
Q2. Service learning helped to improve my understanding of the course material. Mean 3.79/5
Q3. The assigned LEGO labs helped me to mentor the young student participants. Mean 4.4/5
Analysis:

The students "Strongly Agreed" that the labs helped them to mentor the young participants (Q3). Note that the labs were based off the same kits that was used at the schools. Since the assigned labs in the course were fairly hard compared to the level expected at the school, we are not surprised by the assessment.

The students "Agreed" that service learning motivated them and improved their understanding of the course material (Q1 and Q2). This was perhaps because the students were challenged to explain concepts to the children. Thus, they had to take an active role in their studies for the course.

Questions 4, and 5: Questions that assess student's perception about mentoring.
Q4. The young student participants from schools need mentors. Mean 4.67/5
Q5. I enjoyed the mentoring experience Mean 4.43/5
Analysis:

The students "Strong Agreed" on both these questions. The students felt that children truly need help and this perhaps fueled them to take interest in mentoring, thus enjoying the experience.

Questions 6, 7, and 8: Questions that assess service learning in general
Q6. Service learning should be extended to other engineering courses where it is relevant. Mean 4.25/5
Q7. If I were to choose an option for this course again, I will choose service learning over a final project Mean 4.58/5
Q8. If instead, there was an option between Service learning and MATLAB simulation and animation of robots, I would choose Service learning. Mean 3.73/5
Analysis:

Students "Strongly agreed" that service learning should be a part of other Engineering courses (Q6). This was surprising because we felt that Engineering students may not be inclined towards going out to schools with their busy schedule. Ours was the first service learning course in the College of Engineering and this is clearly a message for administrators/faculty to try to incorporate service learning in the curriculum.

Students "Strongly agreed" that they would do the service learning over the project (Q7). This was understandable because unlike service learning which was completed in week 10, the project started in week 11 and was completed at the end of the course, in week 15. By choosing service learning the students were able to keep some free time towards the end to focus on other courses.

Students "Agreed" that they would do service learning over the option of having them do MATLAB (a numerical programming software) exercises which involve programming and animation of manipulators and mobile robots (Q8). We have found that majority of Mechanical Engineering majors lack the interest and skill needed for extensive programming.

3.2.2 Essay type questions: Q9, Q10, Q11

Questions 9. What do you like the most about service learning?

Observations: Based on the answer provided by the students, we conclude that they liked service learning because of one or multiple of the following reasons: it helped them share their knowledge, give back to their community, the opportunity to teach, improve their communication skills, teach critical thinking and problem solving skills, help to learn the course better, getting students interested in Engineering, Robotics, STEM, helped relax from the stress of school, have an impact on the lives of the school kids.

Following are comments from the students:

"I liked getting to share my knowledge with elementary school students. They are curious and need guidance in order to be successful. I felt that I was appreciated and that the students were highly motivated."

"Being able to explain to the students that this is the engineering process, trial and error, is a great thing for them to experience, especially this early in school."

"Working with the student was a lot of fun and I really enjoyed giving back to the community."

"One of the things that I liked the most about service learning was that it helped me do better in the course material."

"Being able to teach young kids how to critical think."

"I loved hearing kids say they enjoyed the experience and how they wish to pursue the same career as me and i enjoyed motivating and encouraging them to pursue a higher education"

"Having the opportunity to share my knowledge and experience to the elementary kids. Getting my point across was somewhat difficult, but I think that's the best part of teaching. I've learned that I have to be more patient and sometimes I have to let the elementary kids have their own thoughts/ideas, and kind of guide them towards the right idea."

Questions 10. What do you dislike the most about service learning?

Observations: Based on the answer provided by the students, we conclude that students disliked service learning because of one or multiple of the following reasons: driving to school, commute and traffic, school is far away, cancelled meetings, 1 hour of meeting/interactions was not enough, very little programming done during meetings, hard to get the children focused, teachers in the classroom did not know much about programming, tracking software was fussy.

Following are comments from the students:

"The school had early releases during the time of the robotics club. So I had lost many hours."

"I'm kind of disappointed that I didn't get a chance to help the students with their LEGO EV3 Program. I think the mentors spent a lot of time on the brainstorming ideas, instead of actually starting the project."

"I did not enjoy the pressure to have to meet a time limit for the service learning. While I understand that this it to ensure the students do meet with the robotics team, I feel a better way would be to have the option to reach a time limit or also do tutorials for the students or clubs. Of course this would require more work for the teacher and students to make the tutorials educational as well as a rubric for the students in the class to follow."

"We spent multiple weeks on just putting the LEGOs together for the board. I would have much rather spent that time with the children on helping them get to know how the programming worked. They had an interest in programming, but there wasn't the time scheduled."

"There was not much that I disliked from me mentoring experience. If I had to say that I disliked something, is that not all students were interested in the topics that the class were talking about. Some of the students were harder to get to listen, so it would make it difficult to get their attention. That would be about the only thing about the service learning that I disliked."

Questions 11. Do you have any suggestions/comments about service learning? Also, any suggestions for next year?

We list some students' comments here. Generally, it seems like student like service learning and would recommend it next year.

"Another thing I think would be beneficial is to have a LEGO introduction lab before service learning begins."

"if the service learning could be started earlier this could help relieve some of the pressure to meet the number of hours needed to receive credit as well as help students with other project heavy classes such as senior have work spaced out a bit better.**"**

"think it would be beneficial to have a guide or lesson outline to provide to the teachers that were in charge of the clubs. I believe it would have helped accelerate the students learning.**"**

"Make sure the mentors get a chance to help the kids at the elementary school with the LEGO EV3 program.**"**

"I felt that a more structured environment with agendas of tasks per week would help to get more things accomplished during the mentors visits.**"**

"I was part of the robotics class that were held on Tuesdays and Thursdays. It took a month for the class and routine to become established, which took away from getting the students further along with their robot projects.**"**

4 Discussion

Our results suggest that service learning improves student learning outcomes. Our conclusion is based on the fact that service learning students scored one grade higher than the students who did the alternate option of project-based learning. Also, service learning provided opportunities for students to serve as role models to young Hispanic students in underrepresented communities.

For majority of the students, this was their first experience with service learning and mentoring of young children, specifically Hispanic and English learners in underrepresented urban and rural communities. Hence some students expressed doubts and uncertainty in their ability to teach the young children. However, this impression changed as they interacted with them. By the end of the program, almost all students were left with the impression that service learning taught them how to communicate hard concepts in a way that was understandable to the children; results that correspond to ABET student learning outcomes 3.g and 3.h.

The students felt that the assigned labs in the class helped them mentor the kids. The prime reason they liked mentoring was the opportunity to give back to the community and how it helped them develop their communication skills and to some extent improve their learning in the course. However, the bigger issues they faced were getting the students focused and finding that 1 hour of interaction was not enough.

It was interesting to note that the overall experience of the students doing the service learning was positive. A majority said that that they would do service learning over project. Also, a majority felt that service learning should be part of other engineering courses. This is important because there is no official service learning course offered in the Engineering curriculum at UTSA. One indicator of the success of our program was that 9 out of the 33 undergraduate

students (about 27%) decided to complete another 30 hours of mentoring to get a service learning certificate from the Academy for Teacher Excellence.

There were some issues in the service learning experience, some of which we will try to address next time the course is offered. Some students had to drive a long distance and/or drive in rush hour traffic to get to the school. Sometimes the schools canceled the meetings due to unexpected campus and/or district required meetings leading to reduced number of service hours. The most commonly faced issue by the students was trying to get the children focused. ATE has already begun addressing the communication and mentor preparation issues in the Spring 2017 semester.

Finally, we present a list of items that helped us in making our first service learning module a success.

1. **Logistics:** It is important to plan the community partners ahead of time and know beforehand club start dates, number of young student participants, and any campus specific details like parking and sign-in procedures. One should plan to be sure that the students could be properly accommodated in a school. If not, students need to be informed of any school placement limitations and the criteria for selecting students for the available slots. After students sign up, they sign the liability waiver and complete district-specific criminal background checks. These things take time and also need to be planned ahead of time.

2. **Have another option for students not interested**. Service learning is not attractive to everybody. For some, it might be a time constraint. It is always a good idea to have an alternative option for students. In our case, the other option was a project where students either build a robotic device or they do a robotic simulation. To keep things fair, the project was scoped out so that it would require students to work 10-20 hours, the same as service learning. To get more people interested in mentoring, we highlighted the advantages of service learning over project on the first day of class.

3. **Costs/time associated with travel:** We were warned by other faculty who have offered service learning that students often complain about the travel time and the mileage cost. We took some effort to ensure that students left campus at a time when they would not have to drive in rush hour traffic, but we were not always successful with that. We did compensate students with $50 (NSF grant), which took care of the gas costs. In the future, we plan to pay students a mileage cost proportional to the distance of the school from UTSA to encourage students to mentor in the schools further away.

4. **Set expectation and clear rubrics:** Establish rubrics for the service learning early on, preferably in the first class meeting. That way students have a clear idea on what to expect. In our case, we gave students full credit if they did 10 hours and/or 10 visits, answered the reflection questions, and the survey at the end of service learning. All students who did service learning scored full points.

5. **Send reminders:** Students are busy and they forget things. It is important to keep them reminded about the various deadlines. Specially, if they are meeting the 10hr/10 visits

criteria, reflection questions, survey. Through the GivePulse system we sent the student mentors reminders 48- and 24- hours in advance of each weekly club meeting.

6. **Cancelled meetings**: We faced some issues when the school cancelled a meeting at the last moment. Because of this, some students wasted time driving to the school. We then instructed the students to get the contact information of the teacher/responsible party in the school and to call before going. Also, because of cancelled meetings, some students could not complete the 10hrs and/or 10 visits. But we evaluated these students on case by case basis, giving them full credit for this part of the rubric.

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