2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #33594

Engaging Minority and Underrepresented Engineering Students to Fight "Sophomore Slump" Through a Summer Research and Enrichment Program (Research)

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Abstract: It is well known that there exists a gap in academic performance between the underrepresented groups and the majority of engineering students. Closing this gap is more challenging in the sophomore year due to a well-known phenomenon in college education known as "sophomore slump", which is more common among minority and underrepresented students and requires institutional efforts to help the students adjust in the sophomore year. In this paper, we present a research project funded by a Student Engagement, Retention, and Success (SERS) grant from the Tennessee Board of Regents. The goal of the project is to improve the GPA and retention rate of underrepresented and minority students by engaging them in a summer research and enrichment program. The project was carried out in Summer 2020. Compared with similar activities in the literature, our program has the following unique features: (1) Low floor, wide walls, and high ceiling; (2) Collaborative learning in a cross-disciplinary setting; (3) Hands-on and real-world oriented; and (4) It was offered online instead of face-to-face. Based on student survey results and Fall 2020 retention rate, the summer program is very successful. This paper explains in details the motivation of the research project, how the students were recruited, the preparation done by the PI and co-PI, how the topics of the student projects were selected, how the students collaborated remotely, the assessment methods, measurable outcomes, and challenges and lessons learned during the process.

1. Introduction

It is well known that in STEM related disciplines there exists a gap in academic performance between the underrepresented groups and the majority of students. This gap is very significant in the College of Basic and Applied Sciences (CBAS) at Middle Tennessee State University (MTSU): the percentage of underrepresented students whose GPA is above 3.0 is 13% less than that of the majority students, and the percentage of underrepresented students whose GPA is below 2.0 is more than triple of that of the majority students. This gap directly contributes to other academic problems; for example, the current retention rate of underrepresented students is 10% less than that of the majority students in CBAS at MTSU. Moreover, this gap gets worse year after year in the past three years.

Closing this gap is more challenging in the sophomore year due to a well-known phenomenon in college education known as "sophomore slump": reflected as either students getting poorer GPA or lower retention rate, or both, in the sophomore year [1] [2]. According to [3], sophomore slump is more common among minority and underrepresented students and requires institutional efforts to help the students adjust in the sophomore year. In a study performed in [8], 20 out of 24 institutions have some kind of programs designed specifically for sophomores. Providing these programs to freshman and sophomore students is a research-proven strategy to increase GPA and retention rate [13].

In this project funded by the Student Engagement, Retention, and Success (SERS) grant from the Tennessee Board of Regents (TBR), we sought effective ways to engage the underrepresented and minority students by organizing the students to perform faculty-led and team-based summer research projects at the end of their freshman year. In particular, we had the following two objectives: (1) To improve or maintain their GPA and (2) To increase retention rate. Specifically, we developed a four-week summer research and enrichment program, in which students performed team project using computer vision, machine learning, microcontrollers, sensors, and other technologies to conduct applied research on Internet of Things and Smart City related topics.

The organization of the paper is as follows: in Section 2, we specify the difference between this project and other ones in the literature; in Section 3, we describe in details how the project was carried out; in Section 4, we present the outcomes of the project; finally, we conclude and discuss potential ways to improve future projects in Section 5.

2. Novelties of Our Project

Among all the programs available for freshman and sophomore students, it has been shown that engaging students via summer research and enrichment programs can significantly improve retention [4] [9] [11] [12], GPA [5] [6] [7], and graduation rates/time [10]. The rationale behind these success stories is that engaging students in the summer program promotes their interests, broadens their knowledge, and fosters a closer relationship between students and their peers and professors, which in turn positively affects academic performance. Different from the previously established summer programs, our project activities had the following novelties:

(1) Low floor, wide walls, and high ceiling: The summer research was based on project-based learning and only required basic knowledge in math, natural sciences, and computer programming to start with. In addition, the participants did not work on a fixed given research topic; instead, they conducted literature review under the guidance of the faculty advisors to come up with their own ideas that are fun, creative, feasible, challenging, and also rewarding.
(2) Collaborative learning in a cross-disciplinary setting: We divided the participants into groups, and each group has students from different STEM majors. By doing so, we would maximize the potential and creativity of each group, and the students could collaborate with others who have different background. By working closely with faculty members and peers, the students had the opportunity to develop peer support and stronger interests and motivations for learning. Note that in addition to gaining technical knowledge, the students also learned team collaboration, which is essential not only in course and capstone projects, but also in their future career.
(3) Hands-on and real-world oriented: The summer program encouraged the students to solve problems that are practical, meaningful, and with real-world implications. With the help of the faculty mentors, the students had the chance to tinker and dabble various prototypes until the perfection of the final product is reached.
(4) It was offered online instead of face-to-face: Due to the COVID-19 pandemic, our campus was closed during Summer 2020, and we had to switch from the original face-to-face setting to remote delivery. The format change created significant challenges, but it also made our project different from existing ones in the literature. We believe that the outcomes of this project help

us better understand the possibility of offering cross-disciplinary summer research project in an online setting.

3. Project Implementation

We divide the description of project implementation into several subsections.

3.1 Participants Recruitment

The recruitment took place in Spring 2020. We designed an application form using Google Forms and a flyer for advertising purposes. In order to reach out to as many students as possible, we asked the Dean's office to email all freshman and sophomore students in CBAS. We also asked advisors in the college's student advising center to print out hard copies of the flyer and gave them to freshman and sophomore students who sought advice from them. There were totally 61 applications, and the decisions were made based on the following criteria: *(i)* Is the applicant a minority or underrepresented student? *(ii)* Is the applicant a freshman or sophomore student? and *(iii)* Has the applicant taken Physics I and a computer science programming course? Among the 16 applicants we offered the position, most of them were minority and underrepresented freshman and sophomore students. Due to the COVID-19 pandemic and the change of the delivery format, 11 students eventually participated in the summer research project. These participants were from 4 majors in CBAS: 6 were from Mechatronics Engineering, 3 were from Computer Science, 1 was from Aerospace, and 1 was from Mathematics.

3.2 Project Preparation

The summer project took place in July 2020 and led by two faculty members, one from Computer Science and one from Mechatronics Engineering. Each faculty mentor led two teams. To make the students ready for the project, the faculty members did preparation before the project started.

(1) Project preparation for Teams 1 and 2

In the beginning of June, an initial Zoom meet was held. The faculty member gave a mini lecture about the applications of computer vision and deep Neural Network based machine learning methods used in various robot related projects. Then, each team member talked about the kind of projects he or she might be interested in working on. It turned out that students in Team 1 were more interested in applying the techniques in self-driving car related applications, while Team 2 members were more interested in applying these techniques in agriculture crop protection, i.e., building a robotic scare crow or automatic plant viability detection. Most of the students were freshman and sophomore: they only had 1 or 2 computer science programming courses and did not have any background in image processing and machine learning. For this reason, the faculty member selected two Udemy courses for the two teams to take so that they could learn the needed knowledge and skills. The Udemy courses were appropriate for this purpose because they are accessible and fast paced, do not require many pre-requisites,

and are delivered in a practical way. We were hoping that the courses could help the students understand the basics of the methodology and quickly delve into hands-on work in their own projects.

For Team #1, the course selected was "The complete self-driving car course – applied deep learning". For Team #2, the course selected was "Python for computer vision with OpenCV and deep learning". Both courses use Python as the main programming language, and they introduce students to basic image processing and display techniques and tools, including Convolution Neural Networks (CNN) in image classification, scikit-learn API, and keras APIs.

All team members were highly motivated and were able to finish the online courses in June.

(2) Project preparation for Teams 3 and 4

The faculty member provided an ELEGOO UNO Project Super Starter Kit for each participant. The kit costed $36 on Amazon, and it comes with 22 lessons. In the last week of June 2020, the participants were asked to complete all the lessons as a team. Before they started working on these lessons, the faculty member gave a tutorial over Zoom, explaining the basics of microcontroller interfacing and Arduino programming. In order to demo Arduino basics and hardware interfacing, the faculty mentor used a Canon EOS M50 Mirrorless Vlogging Camera and Sigma 16mm f/1.4 DC DN Contemporary Lens, mounted on top of a desk by an Arkscan MCM5 table clamp mount. By using Canon's EOS webcam utility, the camera appeared on a PC as a webcam and streamed Ultra High-Definition video of the setup over Zoom. The following topics were covered in the tutorial:

(1) Introduction to Microcontrollers and Arduino
(2) Arduino Programming Basics and Arduino IDE
(3) I/O pins and modes
(4) Using Arduino libraries
(5) Demo of selected built-in Arduino examples including the LED light, buzzers, and the temperature sensor

3.3 Project Idea Selection

(1) Teams 1 and 2

At the beginning of July, the teams reconvened to formally start the project. Team 1 students discussed a couple possible projects they would like to pursue: for example, to identify stop signs on the road, or to locate empty spaces in a parking lot for easy parking. Considering the factor that the project was to be completed within one month, they converged on the project of recognizing and classifying traffic light patterns. The idea was for an autonomous vehicle to detect a traffic light from images captured from its

front camera and to recognize whether the traffic light is currently displaying red, green, or yellow.

Team 2 students debated whether to do the project of creating a robotic scare crow to shun away animal predators to gardens or farms, or to build a robot that monitors the health of plants, and they finally decided on the robotic scare crow project. This project was to be developed on a Raspberry Pi, using images captured from a Raspberry Pi camera as well as motions detected from an IR motion sensor. The team researched on the hardware components needed and decided on the part list.

(2) Teams 3 and 4

In the first week of July, the faculty mentor provided another Arduino kit: ELEGOO Upgraded 37 in 1 Sensor Modules Kit to each participant and divided all the students into two teams. Then, each team came up with two ideas that involve Arduino, sensors, motors, and digital displays. The faculty member discussed the ideas with the teams and help each team choose one. The final project ideas are as follows:

Team 3: The TNT board. There were three team members, and "TNT" is the combination of the first letter of the first name of each team member. The project was to design and implement an interactive board game that consists of six games.

Team 4: Knock lock. There were two team members, and the project was to design and implement a secret lock that would unlock a drawer upon the detection of a knocking pattern.

3.4 Online Collaboration and Teamwork

After the project topics were finalized, all four teams ordered the parts and started working on the projects in the second and third weeks of July. Since the MTSU campus was closed and the COVID-19 cases surged in the summer, the students collaborated remotely using slack, Zoom, text messages, Discord, etc. Because the project involved writing code, some students also set up GitHub repositories in order to collaborate and perform version control. The faculty mentors helped the students along the way by holding regularly status meetings and answering their questions.

4. Project Outcomes

All four teams completed their projects by the end of July, and the last week was mostly used to tinker and dabble. A final report detailing the design and outcomes was submitted by each team. Team #3's work: "The TNT board" has been accepted by the Multidisciplinary Engineering Division of the ASEE 2021 annual conference [14].

Below is the summary of the student survey completed by the participants after the summer research program: (1) all students learned something new and useful; (2) all students believed that the summer program will likely help them in their future study; (3) 10 out of 11 participants thought that they were introduced to undergraduate research and creative work; (4) 9 out of 11

students thought that the summer program increased their self-confidence; and (5) all people thought that the summer program was great and would recommend it to a friend. The students also had the following comments about the summer program:

- Collaboration, working with new technology
- One of the strengths of the program is that it allows to students to choose their project. This makes the students more likely to achieve the goal and it allows for more creativity.
  Another strength of the program is how the students are responsible in total for the success of the project. The students can ask questions if needed but the project will succeed only if the students are able to work together.
- Taught new CS principles quickly
  Collaborative Teamwork Environment
  Problem Solving
  Research Experience and Exposure
- We were able to learn to work with people that have different ideas. Problem solving skills were also able to be developed as many problems occur during the project. Effective communication skills were also able to be develop throughout the course of the project.
- I got to apply my skills and learn new things in a realistic work place setting.
- The benefit of having a time constraint of building a device is ubiquitous. It somewhat turns into a renovative survival skill.
- Independence, flexible schedule, creative freedom
- 1. Learned a very valuable new skill
  2. Research experience
  3. Work closely with other majors on a project
  4. Get to know faculty in a professional setting.
- the summer program taught me to code, wire, and understanding material strength.
- Image recognition
  Neural network
  Machine learning and AI
- Considering the issues with the current pandemic, it helped give better understanding of how to work in a collaborative project with multiple people, especially managing to work together remotely. In addition, it gave us access to learning more electrical system and sensors with the Arduino kits and showed briefly some additional resources we can use at MTSU in the future.

Among the 11 student participants, one graduated and ten continued to be full-time students at MTSU in Fall 2020. Therefore, the retention rate of the participants was 100%, higher than that of all freshman and sophomore students in CBAS, which is 69.1% from Fall 2019 to Fall 2020.

As the delivery method of most courses offered by MTSU switched to Remote, Online, or Web-assisted in Fall 2020, many students had financial difficulties, mental health related issues, and difficulty adjusting to the new learning methods. As a result, there was a significant negative impact to the students' GPA in Fall 2020, caused by the COVID-19 pandemic. Therefore, we did not see a significant improvement over the participants' GPA: among the six participants

majoring in Mechatronics Engineering, the median GPA difference between Fall 2019 and Fall 2020 is -0.0095, which is very close to -0.043, the median GPA difference of all freshman and sophomore students in Mechatronics Engineering.

5. Conclusions and Discussions

In this paper, we present a summer program funded by the SERS grant from the TBR where the goal was to engage minority and underrepresented freshman and sophomore students in CBAS at MTSU via undergraduate research projects. Compared with other works in the literature, our program had the following novelties: (1) The project ideas were come up with by the participants themselves and were real-world oriented; (2) We fostered collaborative learning in a cross-disciplinary setting where the members of each team came from different majors; (3) The participants collaborated online using online communication and collaboration technologies.

All 4 teams completed their projects successfully. Although the negative factors brought by the COVID-19 pandemic somewhat overshadowed the positive impact of the summer program, we still believe that our program accomplished its goal: (1) The post-program survey indicates that the participants were very happy about the summer program and believed that it would help them in their future study at MTSU and (2) The retention rate of the participants was 100% in Fall 2020, clearly showing the benefit of the summer program. The grant we got for the summer project was for one year only, but we plan to seek additional funding from the TBR and other sources to continue the summer program in the coming years. This is to increase the sample size and better verify the true benefits of our program, especially after the COVID-19 pandemic.

All participants of the summer program participated in the research activities remotely over the Internet. Although remote delivery may not be the best way to collaborate, our program outcomes indicate that it is possible to accomplish certain collaborative and cross-disciplinary undergraduate research projects online.

We noticed that some of our participants were very dedicated, hardworking, and creative. Our summer program indicates that when opportunities are provided, being minority and underrepresented could be a strength that motivates the students to do the best work in extracurricular activities.

We believe that the summer program is scalable, since it does not involve significant instructions and assistance from the faculty mentors: the participants were able to overcome most of the technical difficulties with minimal guidance.

Acknowledgement

The authors would like to thank Tennessee Board of Regents for supporting the summer program.

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