Novel STEM Research Programs Could Minimize Attrition in Undergraduate Engineering

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Abstract

Many institutions across the country suffer from high attrition rates in their engineering programs, especially between the freshman and sophomore levels. A semester-long research and development experience can aid undergraduate mechanical engineering students in gaining and reinforcing skills critical to success in their programs. The research opportunity presented to two first-year mechanical engineering students at the University of Wyoming introduced them to engineering concepts such as coding, and project management as well as reinforcing concepts like physical production. The student-researchers were given firm deadlines to design and produce a wearable badge for a "GenCyber" summer camp sponsored by the NSA. The badge needed to harbor a programmable micro-controller in the form of a Microbit, an exchangeable nametag, and a functioning display system. With these requirements in mind, the researchers took full control over all aspects of design, resource management, and production. The result of this research opportunity included a demonstration of an improved sense of unit cost; from the initial design of the badge to the final design of the badge the overall cost declined by 40%. In addition, the researchers gained 50 hours of coding experience in JavaScript and cybersecurity concepts through the summer camp. The student-researchers also got hands-on experience in resource management by controlling and managing themselves, their time, and their equipment. Already, the student-researchers have been able to apply the knowledge gained through the camp in their second year at the university. A research opportunity similar to the one presented can give students the skills they need to further their engineering careers.

Introduction

One of the biggest shocks for incoming undergraduate engineers is the transition from high school to college. With it brings higher expectations, many of which students fail to anticipate [1]. I met with several undergraduate students who are both, enrolled in the University of Wyoming's Engineering and Applied Science Department, and no longer with the program in order to find out why and where they had struggled. We engaged in public group discussions, and recorded notes covering their responses in order to create an ongoing Action Research Project. A common thread among all responses was a general feeling of being unprepared for what an engineering degree asked of its students. The same feeling has been reported in other studies as well [1].

Two students were chosen to participate in an undergraduate research program sponsored by the University of Wyoming during the spring and summer semesters before their sophomore year (and basic engineering courses) started. These students were chosen from a very small applicant

pool because of their success during their first semester. 2018 was the first year the university sponsored a program like this one, which could be why the applicant pool was so small and unvaried. All interested applicants shared themes of high achieving students. This program allowed the student-researchers to gain valuable experience that aimed to make the transition into the second year much more comfortable. There have been other reports on the benefits of summer research projects that aim to allow students to get first hand experience in their field. In most cases, this approved attrition rates between the freshman and sophomore years [2]. The on-campus location gave students all of the resources they needed and allowed the project to run concurrently with the semester. Staff resources were also close, and when students needed a helping hand to guide them back on track, it was never far away. An opportunity like this allows students to test the waters of engineering between their first and second year, thus alleviating the aforementioned feelings of unpreparedness [3].

Methods

The research program began with a meeting between the student researchers and their contact early into the spring semester of their first year. During this meeting, a brief introduction to the project was presented, and deadlines for design, production, and implementation set. Compensation was discussed during the meeting as well. The student's faculty contact showed and gave them the "Microbit" micro-controllers that would act as the brain to the small electronic name tag/device. Along with the Microbit they were given a second larger piece of electronic equipment called a "Motobit." These two pieces of equipment snapped together to form a programmable electronic device that would be used in the upcoming summer camps in five to six months. The students were tasked with this:

- Using all available resources as needed, design a prototype housing for the Microbit/Motobit device
- The device must have a way of identifying the wearer so it can be used as a nametag during the camps
- The device must have a display system consisting of LED lights to display information as needed (current score)
- The device must house and secure a battery for power
- The device must be wearable, visible, and not too intrusive
- Using available 3D printing capability (on or off campus) meet the production deadlines set
- Using JavaScript, Program the Microbit
- The Microbit must have a ranking and leveling system in place so that during the camps, a score can be kept

- The ranking and leveling system must be secure enough that camp-goers cannot compromise it within minutes, yet insecure enough that camp-goers will be able to find patterns and crack the code eventually
- The ranking and leveling system must display on the LED's

Beyond these basic guidelines, no other instruction was given. All decisions were left for the researchers. This project marked the first time either of them had full control down to the smallest detail while working on a design.

The timeline that the researchers were given followed this format:

Early February…….... First meetings and deadlines are given

Mid-April……....Prototype in hand

Mid May…….First summer camp takes place (25 working units)

June/July…….Following camps take place (200 working unis)

As one can see, the looseness of the guidelines compares to the simplicity of the schedule. The deadlines set were hard and unmovable, simulating a real-world experience one might find in a job. Leaving so much open space between checks and giving the researchers freedom allowed them to learn time and resource management themselves, and see the importance of it firsthand. Because the project leaves so much to be determined by the undergraduates who are participating in it, the results will vary significantly from program to program, but in this case, the results are only a piece of a much larger puzzle. The primary goal of a researcher-run program is to allow the students to get real world, hands-on experience in the engineering fields. A 2017 thesis supervision clarifies that action learning can be a critical part of undergraduate engineering learning [4]. The student researchers approached the project in multiple stages. First, they used pencils and paper to brainstorm and design the physical dimensions of the device. They came up with and discarded several iterations before landing on a design that they wanted to take forward. Then, they moved from pencil and paper to the computer and "SolidWorks" CAD (computer aided drafting) software that allowed them to bring their drawings to digital 3D space. Once they were happy with their initial prototype, printing began. They quickly learned the necessity of cost-efficient designs and precise measurements. After three more iterations, they had designed a device that met all requirements. The coding and security aspects of the design were researched and explored concurrently with the design process.

The beauty in this program is that it allows the researchers to discover the best ways to work on projects themselves. There is no structure, so they must create their own. In doing this they learn what works and what doesn't.

An essential piece of the schedule is the first small summer camp. Starting with a small camp gave the researchers a real test of their design to see how it functioned in the camp environment. It also allowed them to make changes and modify their design to flush out any final bugs before the high traffic, multi-week camps started.

Results

Only two researchers received the opportunity to participate in this program, and unfortunately, this left us with an objectively small sample size. Other engineering students were spoken to in a public setting, both former and current, on the potential benefits of the program.

Both participants reported using skills learned during the program during their following semester at the university: Their 50 hours of coding experience was used to help sort data and construct graphs for classes. Their CAD experience came into play when they were able to model problems in an online space to assist in solving them. Their project oriented mind set gave them an edge with planning and completing all assignments and projects on time. Both participants reported, from their observations, that they were significantly more prepared than their classmates who did not participate.

A newspaper article from Stanford University also reports that during summer research projects, students that attended gained skills and experiences that they could find useful during and after their undergraduate degrees [5].

All students reported thinking that they would enjoy the experience.

Four out of the seven students polled believed that this experience was just as meaning as an internship, if not more because it simulated a real-world engineering experience better than a traditional internship program could. One student did not believe the experience would be as meaning as an internship, but did not elaborate further. Two students who responded with an answer of "unknown" felt that they did not have enough knowledge of internships to give an accurate answer. It should be noted that a 2015 study found that it was difficult to accurately document the objective differences between summer research opportunities and lab work in the field [6].

Most students agreed that an opportunity like this would have helped them decide to stay in engineering. One peer who left the college of engineering between their freshman and sophomore years stated, "Considering that I believe it would have helped me understand the fundamentals and concepts of math and science better, and therefore helped my grades, I do believe that this program would have affected my decision continue as an engineering student."

Table 1 - Responses by Participants of the Program

Was the experience enjoyable?	Was the program better(+), worse(-), or the same(=) as an internship?	Did the program influence your decision to continue in engineering in a positive way?
Yes/Yes	+/Unknown	Yes/Yes

Table 2 - Responses by Questioned Peer Group

Does the experience sound enjoyable?	Does the program sound better(+), worse(-), or the same(=) as an internship?	Would the program influence your decision to continue in engineering in a positive way?
Yes/Yes/Yes/Yes/Yes	+/+/+/-/Unknown	Yes/Yes/Yes/Yes/No

When one looks at the multiple iterations that the two participants made throughout the program, it is apparent that they learned valuable lessons about resource management as well. From the first prototype 3D printed, to the final iteration used there was a 40% decrease in price per unit ($17.50 to $10.50 USD), while structural integrity did not suffer.

Limitations

The most significant limitation in this study was the sample size of two students who participated and five who agreed to the public question session. Because of this small sample, the results of this study cannot be generalized. The current layout of the program is built for a small number of students to participate. Some things would have to change in order for the program to accommodate more students. This project was tailored towards Mechanical Engineering undergraduates, and thus focused on physical design and implementation. With a few simple changes, this project can be made to fit almost any discipline of engineering.

Conclusion

The results in this study begin to indicate the presence of a relationship between university-sponsored engineering programs and how confident/prepared an undergraduate engineering student is for their sophomore year. How confident and prepared a student feels going into their sophomore year plays a direct role in their decision to stay with the program [1]. This study was not conducted to solve the problem of engineering attrition rates by itself; instead, it was done to show how an effective internship like experience could be given to students during their freshman semesters. This program gave freshman engineering students a taste of what an entry-level engineering job can be. The students are given real engineering based tasks that they will use further into their engineering degrees. Experiences like the ones provided by this program are hard to come by in a regular engineering schedule. Even in labs students do not get to experiment, design, implement, and test their creations. In addition to everything else, this program allowed creative thinking and problem solving. Students that participated and those who attended the public polling session agreed that a program like the one described above would be largely beneficial. Most believed that the program would help positively influence

undergraduate engineers who are teetering on the edge of leaving the program. To take this idea further, one needs to implement a system that allows a larger group of participants without sacrificing any of the attributes which define it.

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