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Remote Research for Undergraduate Students: Summer Undergraduate Research Experience (SURE)

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This evidence-based paper will review the outcomes of a recently developed summer research program for undergraduate students. The Center of Transportation Research & Implementation (CTRI) at Minnesota State University, Mankato (MSUM) created a remote research program for Summer 2020. Along with others across the United States, MSUM went under COVID-19 lockdown for the unforeseen future during the Spring 2020 semester. The university cancelled access to most campus laboratories and brought a halt to all experimental research conducted in these facilities. Moreover, a significant number of undergraduate students lost their internships for Summer 2020. With these two substantial changes, CTRI created the Summer Undergraduate Research Experience (SURE) program. CTRI contacted a donor who donated a funding for a single undergraduate research project (pre-COVID) and asked to make changes in the funding process to benefit multiple students. With the adaptation approved by the donor, the research center asked the faculty to submit proposals for undergraduate research projects that the researchers can conduct at their homes.

The proposals requested projects to employ 1 – 4 undergraduate students with a limited, supplies-only budget (<$500). The supplies of the approved proposals were mailed to the students mid-May. The students worked on their projects throughout the summer at their homes with online guidance from their project advisor. In Summer 2020, five research projects that were related to transportation, utility, and energy infrastructure were funded. Each project had a unique theoretical background. An important selection criterion was the potential for the project to be expanded upon into a full undergraduate research project in the 2020-21 Academic Year and that may lead students presenting at the virtual National Conference on Undergraduate Research (NCUR) 2021. The initial findings of the project were presented to the research center via a Zoom conference call at the end of Summer 2020. Moreover, the groups that concluded their projects on time also presented in national platforms, including NCUR.

The impact of the SURE program on undergraduate researchers were assessed via follow-up survey and meetings. This paper focusses on the impact of the SURE program on the students' technical ability, communication skills, educational experience, and future professional experiences. Additionally, the advisors provided positive feedback on their experience with the

projects and undergraduate researchers. The initial success of the first SURE program caught the attention of the Undergraduate Research Center (URC) of the MSUM. URC adopted SURE as a permanent program and funds summer research projects, especially from disciplines that typically receive limited financial support.

Introduction

In March 2020, just like almost every other higher education institute, Minnesota State University, Mankato responded to the COVID-19 pandemic and went to emergency remote teaching for the rest of the 2019-20 Academic Year. All engineering undergraduate courses were offered online (synchronously and/or asynchronously) for the second half of the semester. Moreover, student access to all campus facilities, including laboratories was cancelled until further notice. While the outstanding efforts of the university made it possible for students to continue their programs, it was undeniable that they missed certain vital components of the undergraduate education. Emergency remote learning may have provided a needed alternative to classroom teaching under the extraordinary conditions that the higher-education institutions had to work with. However, they failed to replace the experiential learning that would be not only meaningful, but also essential to an undergraduate student depending on their enrolled programs (Dobbs-Oates et al. 2020). As it is already stated in multiple publications in literature, the lack of hands-on experience was expected to cause a potential decrease in student enrollment (Qiang et al. 2020). The recent statistical data supports this perspective and points out that nationwide enrollment to undergraduate programs decreased by ~8% (N. S. C. Research Center).

In addition to missing their opportunity to get hands-on experience on campus, a significant number of students reported to lose their internships interviews/positions for Summer 2020. Some great institutes such as National Science Foundation's Research Experiences for Undergraduates, Council on Undergraduate Research, National Center for Atmospheric Research and National Oceanic and Atmospheric Administration could put their resources together to make changes with their research/internship programs for Summer 2020 (Sloan et al, 2020). Some of the changes that these institutions came up with were virtual internships, virtual professional development-focus programs, virtual camps/summer courses, and remote research opportunities. However, not every institute/private engineering firm/governmental department had the resources to make such changes to be able to offer virtual experiences for the undergraduate students that they plan to enroll.

Experiential learning is an important tool that helps students grasp the theoretical knowledge, especially when it is focused on solving real-world problems (Kularatne et al. 2021, Almedia et al. 2009). It also helps student growth by supporting their critical and innovative thinking, motivation, curiosity, individuality and effective communication (Gorghiu and Santi, 2016, Zydney et al., 2002). Therefore, Center for Transportation Research and Implementation (CTRI) wanted to provide an alternative to the engineering students who lost their experiential learning opportunities due to extreme conditions of the pandemic. With College of Science, Engineering and Technology (CSET) Development Director and a private donor, CTRI proposed a remote research program called Summer Undergraduate Research Experience (SURE).

Program development

CTRI followed a planning strategy, successful examples of which can be found in literature (Britt and Shoults 2021, Kularatne et al. 2021, Qiang et al. 2020). CTRI reviewed the extensive literature on the experiential learning, remote learning, and take-home experiments; and considered the documented foundational concepts to develop SURE.

In his 1984 publication, Kolb discussed "Three Models of the Experiential Learning Process" (Lewin, Dewet, and Piaget), and identified their common characteristics. Quoting Jerome Bruner, Kolb stated that the emphasis of experiential learning is on the process that concepts are derived from, not on the outcomes. According to Kolb, knowledge is created through the transformation of experience and this makes experiential learning a continuous process (1984). Therefore, CTRI defined that the research projects under SURE program must have processes that will help students apply and create knowledge. As Qiang et al. (2020) discussed and documented on their recent paper, remote research projects that will provide such learning experiences would fall in one of these four categories: question-driven literature review, visualizing experiments from virtual scientific resources, performing safe and simple take-home experiments, and the computational approach.

There are many successful examples of take-home experiments used as a teaching tool for undergraduate engineering courses. Jouaneh et al. (2012) provided low-cost hardware and

software to undergraduate mechanical engineering students to perform simple experiments for their analysis level (3XX) and design level (4XX) technical program courses. The experiments were designed to help students' conceptual understanding of the course material and the application of the theoretical content. The success of the application was assessed via pre- and post-experiment quizzes and an anonymous survey. The results of the pre-and post-experiment quizzes indicated an increase in the students' understanding on the theoretical concepts. Via the anonymous surveys, which had a high (~84%) response rate, majority of the students reported that they found the experiments convenient to perform. One of the most remarkable outcomes of the study showed that, even the students that reportedly struggled with the experiments stated that they were interested in taking more classes with take-home experiments. There are many other examples of take-home experiments that are used as practical alternatives to traditional laboratory experiments. Even though, in this study, we did not adopt take-home experiments as an alternative to traditional laboratory experiments by choice, we still would like to highlight its advantages. Traditional laboratory experiments can be logistically difficult due to long contact hours. This problem especially affects student that commute and/or have additional responsibilities (dependent care, jobs and the like). If designed and applied properly, take-home experiments can provide hands-on experience even to classes with high enrollment. Cimbala et al. (2006) applied take-home experiment as an assignment to analysis level (3XX) fluid mechanics class that had 240 enrolled students successfully. Take-home experiments are excellent alternatives to traditional laboratories that are labor-intensive for instructors.

For projects that have a computational approach, CTRI considered the experiences of the faculty who delivered courses with laboratory components remotely during Spring 2020. Just like almost every other higher education institution, engineering programs in Minnesota State University, Mankato offered alternatives to laboratory experiments during COVID-19 lockdown. Some of these alternatives were simulation labs, and virtual labs. Both of these options were practical choices that would provide meaningful student experiences under pandemic conditions. However, both of these options had constraints, such as hardware, software availability, constraints of preferred/available software, and the like. Therefore, the authors of computational project proposals submitted to the SURE program are suggested to consider these limitations.

SURE Program Details

Many studies on undergraduate research state its positive effects on engineering and science education. Participating in an undergraduate research project improves student persistence (Barlow and Villarejo, 2004), creates an opportunity to develop a mentoring relation with faculty (MacLachlan, 2006), cultivates life-time learning, and increases student interest in pursuing a graduate degree (Eagan et al. 2013). On the account of these positive impacts, undergraduate research has always been an established part of education in engineering programs of CSET. In fact, there are an increasing number of undergraduate courses offered with a research component implemented in the course to involve larger, more diverse undergraduate students groups with research (Bangera, Brownell 2017).

Taking all the information provided into account, CTRI set the goal of SURE as to engage as many students as possible with research and faculty via remote research activities. For SURE, CTRI collaborated with CSET Development Director and a private donor. A funding opportunity, which was provided by the donor (pre-pandemic) to support one undergraduate research project, was repurposed to give a meaningful professional experience to multiple students that suffered from cancelations due to the pandemic.

Thanks to the quick responses of each stakeholder, CTRI was able to announce Call for Proposals to faculty of Engineering Programs in late Spring 2020 semester. In the Call for Proposal, CTRI suggested several research methods, including but not limited to take-home experiments, analysis of historic data, building a prototype. Per the mission of the center, CTRI suggested research topics on transportation, utility, and energy infrastructure; however declared that strong proposals on other topics were welcome. Below are the details of announced logistics:

- Group of 1 – 4 undergraduate students would work on the research together
- Budget was limited to $500 per project (stipend or materials).
- Students must be hired and start their research by mid-May.
- Research projects should be designed to be student-led; and faculty should be available for regular meetings and advising.
- The scope of the projects should be set so that students can wrap their investigations by Friday, July 16th, 2020.

- Findings of all projects would be presented to an audience (representatives from CTRI, CSET, private donor, along with other researchers and their faculty advisors) on the week of Monday, July 27th 2020 via Zoom.
- Research projects that were likely to be presented at National Conference on Undergraduate Research (NCUR) and/or to lead to a new externally funded research were given priority in selection.

Interested faculty submitted a two-page proposal that provided:

- brief outline,
- budget plan,
- number of students that were expected to be involved,
- explanation on how the project could be expanded into an externally funded undergraduate research project,
- explanation of how the results could be implemented into a faculty research project,
- explanation of how project addresses transportation, utility, or infrastructure research (if applicable).

After a two-week review process, five research projects from multiple engineering disciplines were funded via SURE. The funded project topics and brief details are provided below:

ASHRAE Demonstration Mini Air Handling Unit Model for Student Outreach and K-12 Education Activities (prototype development, Mechanical Engineering Emphasis)

Chloride Stratification and Infiltration in Stormwater Ponds (take-home experimental research, Civil Engineering Emphasis)

Development of Autonomous Snowplow (prototype development, Mechanical Engineering Emphasis)

Infrastructure Asset Management Implementation for City of Richfield (data analysis, Civil Engineering Emphasis)

Road Salt Transport across Ditch Slopes (take-home experimental research, Civil Engineering Emphasis)

Even though their topics were on different engineering disciplines, all of these listed projects offered similar experiences to undergraduate students in their respective focus areas. Projects required researchers to

- Develop a self-led, faculty-guided research methodology (process)
- Produce/gather data to investigate a theoretical topics or develop a prototype for the suggested topic
- Operate equipment/software
- Conduct a literature review
- Communicate scientific findings via written and oral presentations.

For the listed five projects, eleven undergraduate students developed their research plan and worked with a faculty advisor, remotely. Below are the details of their experience.

Program Assessment

Student Experiences

SURE Program students were provided their stipend and/or materials by Friday, May 15th, 2020. They developed their investigation plans (individually and/or as a group), regularly met with their respective advisors, and presented their progress over a zoom meeting on Friday, August 7th, 2020. After the projects were concluded, the authors' of this paper requested feedback from the participants to assess the program. Since SURE was an experimental initiative designed within a very short period, the assessment of its execution, its impact, and experience of the participants was vital to improve it. The authors sent an anonymous survey link to participating undergraduate researchers. The survey was completed by seven students (~63%). While the authors acknowledge that the sample set is not large enough to be statistically significant, there were strong agreements in the students' answers that can be used as indicators of student experiences. Participants asked 24 closed- and open-ended questions about their undergraduate education and their SURE projects.

All participants described themselves as undergraduate students in an engineering program (1 sophomore, 4 juniors and 2 seniors). 71% of the participants (5 out of 7) stated that their initial professional plans for the summer (internship position, scheduled field work) were negatively impacted (canceled or changed form) due to COVID-19 pandemic. As given in Figure 1, SURE was the first undergraduate research project of the majority of the participants (5 out of 7) and was the first **self-led** research project of all participants. Participants reported that they worked on their projects ~8 hours/week (on average) for 24.5 weeks (average). This average project duration indicated that most of the projects had scopes too large to be concluded within the given timeline, and our conclusion was supported by student answers to related open-ended questions.

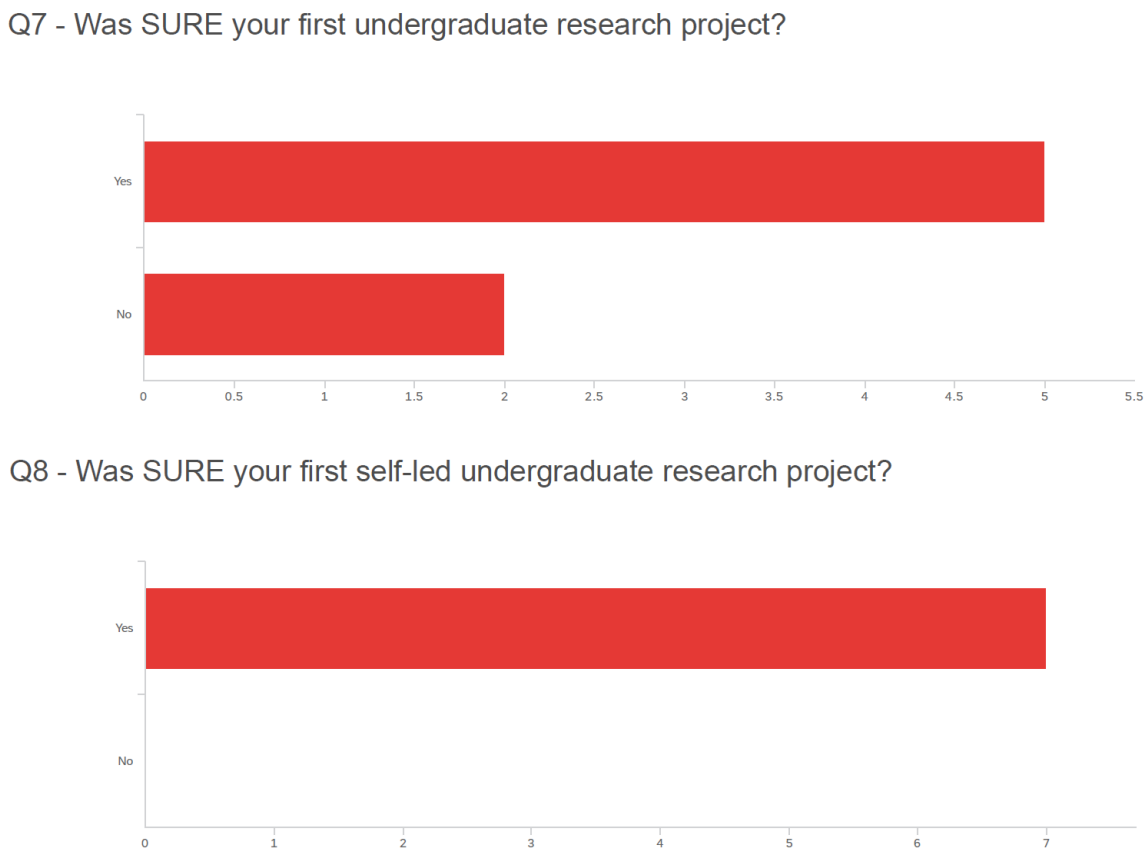

Figure 1. Anonymous student feedback for Summer Undergraduate Research Experience Program 2020 (Questions 7 and 8 via Qualtrics.).

Most participants (5 out of 7) stated that they received support from their project supervisors frequently (weekly/biweekly). Students were asked what skills they gained during their projects

(Figure 2). Based upon their answers we can state that the students gained/improved fundamental hard and soft skills. All students stated that they learned/developed experimental procedures, the majority of the students stated that they learned how to operate equipment/software (4 out of 7), conduct a literature review (4 out of 7), write/present research professionally (4 out of 7), and how to work effectively with others (5 out of 7). Students also reported that they learned to work remotely and time management. (via the option "*Other"*).

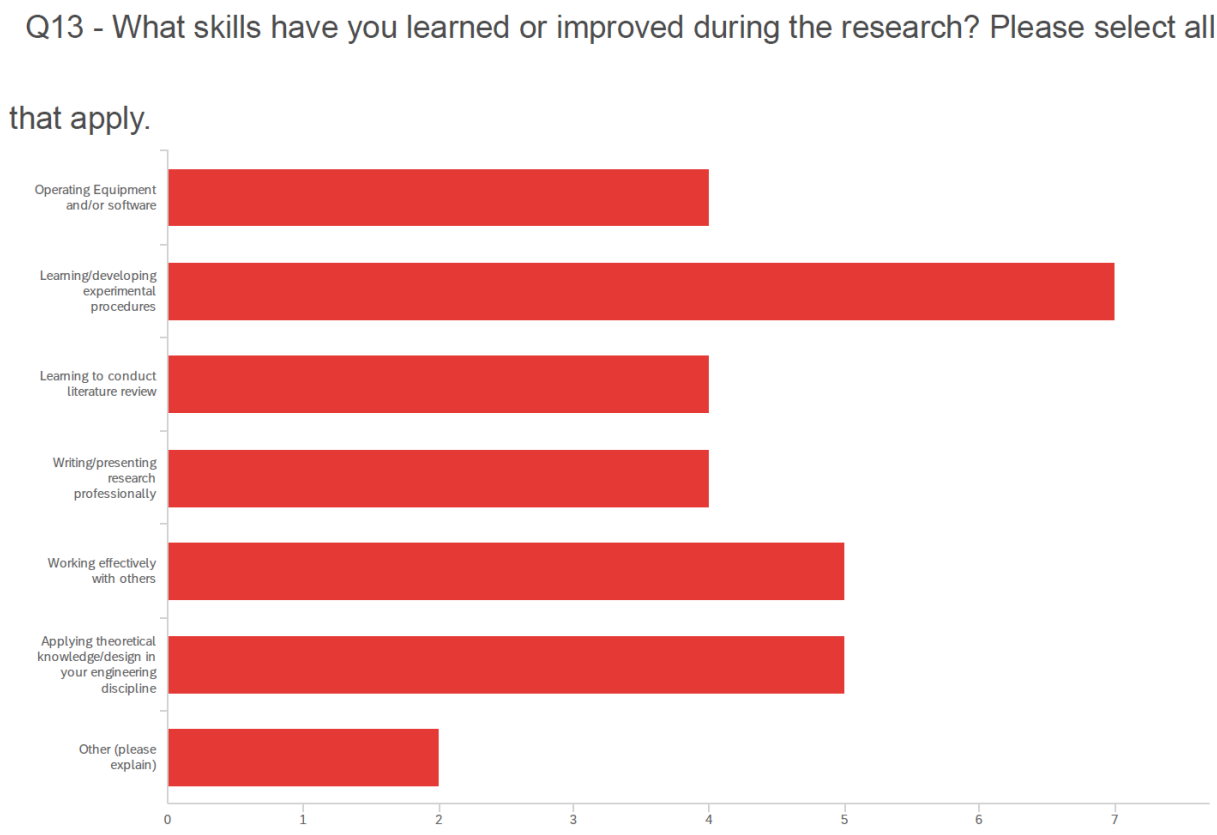

Figure 2. Anonymous student feedback for Summer Undergraduate Research Experience Program 2020 (Question 13 via Qualtrics.).

Authors' assessed the impact of SURE on participants' undergraduate experience via both close-ended (Figure 3) and open-ended questions. Students rated the impact of their SURE experience on their undergraduate education as positive (very positively (4 out of 7) and somewhat positively (2 out of 7)), and provided the following comments:

"Applying what we learn in our classes has helped to solidify my understanding in the material. Further, I've learned a lot of additional information and developed technical problem solving skills."

"SURE provided more opportunities for research and design experience. The project helped me discover my passion for robotics and influenced me to apply to graduate school."

"It gave me more excitement for what I am studying because I can see and work hands on."

"SURE was a great opportunity to work on a project."

"SURE experience helped view in class problems in the real world"

One participant stated that their SURE project did not have a big impact (positive or negative) on their undergraduate experience, because their project did not make significant progress. This unexpected delay was caused by the participant's (and their advisor's) inability to receive historic data from a third party. This feedback is noted to be added as a proposal evaluation criteria for the future offerings of SURE.

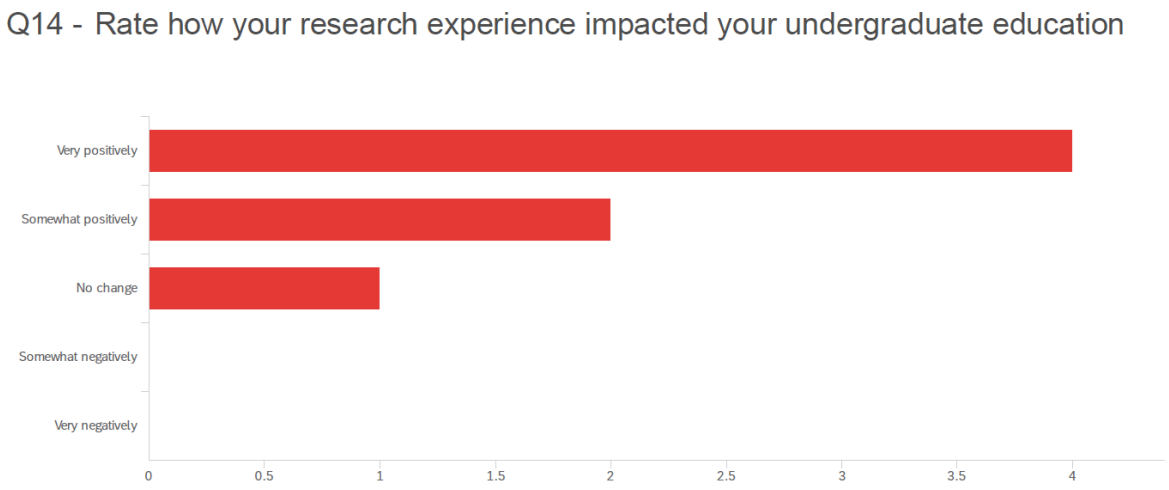

Figure 3. Anonymous student feedback for Summer Undergraduate Research Experience Program 2020 (Question 14, via Qualtrics.).

Overall, the SURE experience helped retention by increasing participant's desire to finish their undergraduate program (Figure 4). It even sparked a desire in some students to pursue a graduate

degree. The majority of the students (4 out of 7) stated that the SURE program lead to new opportunities such as new research, publication, presentation, or participation in a student competition. All except one participant stated that they could add their SURE project to their resume/portfolio as an achievement and all participants stated that they mentioned SURE during a professional interview for an internship, assistantship, research position and the like. All participants that completed the anonymous survey stated that they would recommend SURE to other undergraduate students.

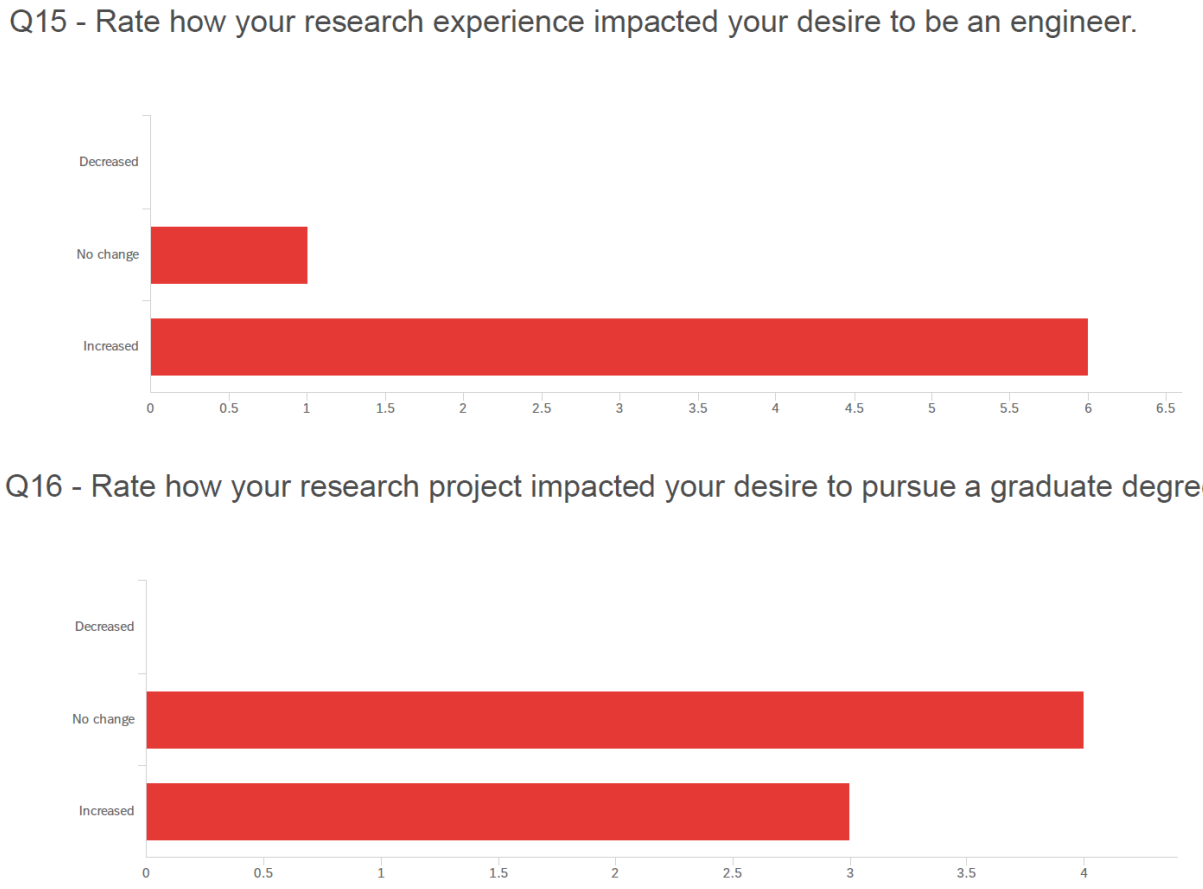

Figure 4. Anonymous student feedback for Summer Undergraduate Research Experience Program 2020 (Questions 15 and 16, via Qualtrics.).

While none of the students stated any negative impact of the program (a decrease desire in finishing their program or working in their respective field and the like) there are some suggestions for improvement. Based upon the participant statements, none of the projects were

concluded within the timeline stated by Call for Proposals. Multiple participants suggested improvement in planning and timeline. Considering that SURE was an inventive plan that was developed in a short-duration due to time and budget limitation, constructive comments of students on planning and timeline of the program was expected and welcomed. We would like to note that, by the end of 2020-21 Academic Year, 4 out 5 funded projects were concluded and 3 projects were presented to wider audiences at different platforms.

Conclusion and Future Work

Summer Undergraduate Research Experiment (SURE) was designed to provide a learning opportunity for interested undergraduate students. Students developed their experimental setup or prototype at the convenience and security of their homes with the remote guidance of faculty. Advisor faculty held progress meetings as needed to verify methodology, review findings and provide other guidance. SURE provided students an authentic research experience that developed their professional skills.

Considering all the circumstances SURE was a successful first attempt. Via the assessment survey, participating students provided positive feedback with some constructive comments to improve the program.

While the pandemic is far from being over, research and data already points out to an evolved higher education understanding for the post-pandemic world (Qiang et al. 2020). Both facilitators' and students' positive experience with SURE led to a permanent remote undergraduate research program. Undergraduate Research Center (URC) of MNSU followed the first SURE program closely, and examined the feedback provided by first group of participants. URC adopted the SURE program and announced a university-wide Call for Proposals in Spring 2021 semester (for Summer 2021). URC accepted research proposals for all undergraduate programs of the university, and priority was given to the proposals from programs that are historically underfunded. Findings of SURE 2021 research projects were presented by students as a poster during an end of summer Research Apprenticeship Program (RAP) and Summer Undergraduate Research Experience (SURE) virtual poster event. We believe programs like SURE can reach out to more students and provide them with a meaningful professional development opportunity during their undergraduate education.

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