Effective Methods to Promote Undergraduate Research in Civil Engineering

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ABSTRACT

In recent years, various engineering disciplines of universities and national agencies have shown increasing interest in promoting undergraduate (UG) research experience. The department of Civil Engineering at the large Midwest public university has promoted UG research in different ways aligning with the College of Engineering (COE) at the university since 2018. This effort aims to provide research opportunities and enriched learning experiences to a broad range of UG students. In addition, these efforts are expected to improve undergraduate students' persistence and retention in engineering fields and support the growth of graduate programs.

Although it is an undergoing research, this paper explores several practices to promote undergraduate research in the College of Engineering at the university and introduces a survey that was conducted to evaluate the current status of UG research in the department of Civil Engineering in 2018. Based on the survey results, Undergraduate Research Committee (URC) of Civil Engineering has suggested plans to improve the system of undergraduate research program in the department.

INTRODUCTION

Undergraduate students can gain various benefits by conducting research to foster relationships with faculty members, discover their interests, and explore and prepare for future academic or professional pursuits. Throughout the research process, they can enhance critical and analytical thinking skills, learn how to collaborate and work effectively as part of a team, and develop problem solving and communication skills. The importance and effectiveness of undergraduate research have been highlighted in past studies. Kuh (2008) mentioned that engaging in undergraduate research is identified as a High Impact Practice (HIP), as experience that increase student retention and success, and many research studies show that even early engagement in research is beneficial for students, especially for students of opportunity on multiple levels [Carpi et al., 2017; Eddy & Hogan, 2014; Freeman et al., 2014]. Although UG students can gain different levels of relevant skills, attitudes, and conceptual understanding in the same time of research, they can get confidence in presentation skills within a relatively short time and show the improvement in identifying patterns in data and logical argument in the experiences [Bhattacharyya et al., 2018].

In recent years, not only universities but also various agencies have tried programs intended to encourage undergraduate (UG) students to involve in research. Specially, science, technology, engineering, and math (STEM) disciplines have more opportunities for students to involve in UG research. National Science Foundation (NSF) has supported a large number of Research Experiences for Undergraduate (REU) sites [https://www.nsf.gov/crssprgm/reu/] in the nation. Although each REU site has its own unique features, they aim to provide opportunities and engage a diverse body of students from underrepresented groups, minorities, and students from

academic institutions where research opportunities in STEM are limited. The Ohio State University (OSU) also has several REU-sites across multiple disciplines; the majority of UG students at these sites have been invited from other institutions. In addition, the Office of Undergraduate Research at the university is aimed at enabling undergraduates to stand at the center of creation and dissemination of knowledge. This office provides and updates various information regarding undergraduate research opportunities for diverse disciplines of the university including STEM and non-STEM majored students. They also organize various UG research forums and events, and the university provides various UG research opportunities such as fellowships and scholarships. In addition, the College of Engineering (COE) at the university also provides Summer Undergraduate Research Fellowships (SURF) and Undergraduate Research Scholarships (URS).

Among engineering disciplines, more civil engineers are needed in the society with the projected near-term needs ailing with new and current degrading infrastructure systems. [Troy et al., 2016]. In addition, new challenges and opportunities are arising and therefore new professionals and researchers are needed to deal with these problems. The department of Civil Engineering (CE) at the university has promoted UG research in different ways aligning with the College of Engineering since 2018. This effort aims to provide research opportunities and enriched learning experiences to a broad range of UG students in the department. Eventually, these efforts are expected to improve undergraduate students' persistence and retention in engineering fields.

Lent's Social Cognitive Career Theory (SCCT) has been utilized in engineering education to understand undergraduate students' major choice and engineering career development [Lent et al., 2002]. The SCCT explains that several factors such as person background, self-efficacy, outcome expectation, and environmental supports and barriers either directly or indirectly impact students' career choice and future work performance. In this study, we utilized SCCT to understand how CE students perceived environmental supports and barriers is related to participating in research, which in turn may impact research career decision makings. For example, Dolan (2016) reported that proving an UG research opportunity for engineering students benefits them to explore the research and pursue research career. Thus, supporting undergraduate students to participate in research can be one way of supporting students to pursue research career. However, there is a gap in literatures what are the supports and barriers for CE undergraduate students to participate in research.

Research questions for this study are as following:

RQ #1: What are the supports and barriers for CE undergraduate students to participate in research?

RQ#2: How do CE faculty members support undergraduate students' research experience?

This paper will also provide possible interventions to support undergraduate students' research and how these interventions will promote undergraduate research in the department of Civil Engineering community.

BACKGROUND

Why the number of undergraduate researchers has been decreasing in Civil Engineering

As briefly mentioned in the previous section, there are many research opportunities for undergraduate students at the university, and faculty members in the department of CE have also individually recruited undergraduate researchers for their research projects. However, it has been observed that senior students were graduating without knowing these research opportunities, or they learned about these opportunities when they were about to graduate. The author has served as a member of Undergraduate Research Committee (URC) in both the COE and the department of CE since 2017 and 2018, respectively. It has been observed that the number of UG researchers in CE is relatively small and that the students are less active compared to other departments in COE. There was zero to one student applied for Undergraduate Research Scholarships (URS) program of COE each semester and Summer Undergraduate Research Fellowships (SURF) programs in 2017. In addition, participations in various UG research forums at the university were very limited in 2017 comparing to other departments.

Faculty members in CE have their own research projects and work with undergraduate students, but they have approached and hired targeted undergraduates for the needs of their projects. Usually, excellent students in the class have a higher chance to get offers from faculty members. Therefore, a broad range of students could be unaware of these research opportunities. In the website or by circulating emails, other research opportunities in the university such as URS and SURF programs are well announced to students. As shown in the website (https://advising.engineering.osu.edu/current-students/honors-undergraduate-research), they require minimum qualifications, and students need to follow the application procedures. However, students should have their own advisor to work with and clear research ideas for developing a proposal. COE students at the university can submit their applications including their own research proposal to URS program during three windows in a year, but it should be submitted three semesters (at least two semesters) before their graduation in order to complete the requirement. URS also requires a research thesis before the graduation so that students can receive the designation of "Graduation with Research Distinction" or "Graduation with Honors Research Distinction". Only difference between two designations is a GPA limit. Applicants should hold GPA above 3.4 when they apply for URS and each semester until their graduation to achieve the Honors Research Distinction, while Research Distinction requires GPA above 3.0. Additionally, students should take research courses before the graduation. Although these courses are designed for students to successfully write and complete their thesis before graduation, it could be considered as the extra courses for students. The proposals should be reviewed and approved by members of UG Research Committee (URC) of COE for the levels of scholarships, and their thesis should be reviewed and approved by their advisor and thesis committee members. Therefore, passing through the URS program could be a great achievement for students. The SURF program at COE is open for application one time in a year since this program supports students during summer semester for about 10 weeks. It is designed for undergraduates for their first research experience so that students have only one chance to apply. Since research novices are applying for this program, the requirement is much lower compared

to URS. However, it also requires a research advisor who can support appropriate research before submitting applications, and freshmen and sophomores are applying for this program in general.

It should be noted that there are UG researchers who individually work with faculty members in CE but do not apply for URS or SURF programs and do not attend any internal research forums in the university due to various reasons.

How to determine the number of undergraduate researchers in the department

It was not simple to determine the accurate number of undergraduates who are involved in research in the department. The number of URS applications was limited to evaluate the number of undergraduate researchers since there were several types of undergraduate researchers in the department. Some students are UG researchers supported by research projects and contracted by the university based on the period of involved projects. Other students are hourly-based researchers still funded by projects, and their times and responsibilities can be flexible in the contract. These UG researchers can be easily found by the department, while it is not easy to count the number of UG research volunteers who are working with faculty members in research labs without any contract and payment. These students can focus on their own research interests rather than those of advisors since they are not required to complete certain tasks for contracted projects. Therefore, it could be more flexible for students but could involve less responsibilities and retention of students. Their research hours vary, and they can leave the lab in the middle of the semester with or without notice to their advisor despite the research effort and time of the students and advisor. It is one of the difficulties for determining the number of UG researchers. Annually, the department collects the entire number of advised UG students of each faculty member. However, it does not include students' identity; therefore, one UG researcher can be multiply counted by few faculty members, and faculty members can miss the research volunteers and students who performed research for short periods.

EVALUATION OF CURRENT STATUS

In order to evaluate the current status of undergraduate research in the department and design future strategies to facilitate UR research, Undergraduate Research Committee (URC) at Civil Engineering conducted surveys of both students and faculty members in the autumn semester of 2018. The surveys were separately designed for faculty members and currently enrolled students in the department using Qualtrics. The initial questions on the student survey were divided into two for those who have research experiences and those who do not. Total 98 undergraduate students (n= 98) participated in the survey. Among them, 14 students are currently engaged in research, and 84 students have not had any research experience

Survey Questions and Results

<u>Group 1: UGs who engaged in undergraduate research with a faculty advisor (n=14)</u>

Most of students found their faculty advisor from a class (4 out of 11) or via emails (3 out of 11). 2 out of 11 students were referred to a faculty advisor by someone else, and 2 out of 11 students actively looked online and asked their academic advisor for assistance. 3 students did not answer this question. Before finding a research lab, 7 out of 11 students spoke with the faculty advisor, and 3 students spoke with 2 or 3 multiple faculty members to ask about research labs. Only one student was not able to find a research lab to join but was approached by a faculty advisor. Most of students have been aware of the URS program and its options of Research Distinction. 3 out of 14 students knew about the research option of volunteering, 6 out of 14 students knew about the independent study option, and 8 out of 14 students knew about hourly paid research positions. 50% of students started their research experience in their junior year, 25% of students started in freshman and sophomore years, and the remaining students started in their senior year. However, around 50% of students answered that sophomore year is the best time to begin a research experience, and the other half students answered that junior year is the best time. They agreed that sophomore and junior years are the best time to begin having research experience. Students identified various challenges in getting involved in research such as figuring out option and opportunities that were out there, research time and their commitment, finding advisors and how to approach them, and lack of confidence. More than 65% of responded students suggested better and more exposures of undergraduate research in the department, further encouragement, and early updates of research opportunities.

Group 2: UGs who have not experienced research (n=84)

Total 84 students participated in surveys, but 4 students did not answer few questions. 83% of responded 80 students were aware of undergraduate research, and 60% of the 80 students wanted to involve in UG research. However, 20 students did not know how to get involved and what opportunities are out there for them. 16 students could not find the appropriate time for starting research, and 4 students could not find a right professor to work with. However, 60 out of 80 students have not talked to any faculty member yet, and 20 out of 80 students discussed research with faculty members or potential research advisors. They provided various answers for how they can get information to involve undergraduate research as follows; Civil Engineering website (70 out of 84 students), announcements in class (42 students out of 84 students), emails from faculty (61 out of 84 students), posted flyers (30 out of 80 students), Civil Engineering seminars (16 out of 84 students), or direct contact with faculty members (45 out of 84 students).

Faculty Members (n=24)

Among total 36 faculty members in the department, 24 members participated in the survey. Therefore, around 67% of the faculty participated in this survey, and it is much higher than the participation rate of students, which is around 12% (84 out of around 800 students). In the survey, 22 faculty members who responded questions are currently advising/co-advising 2 or 3 undergraduate researchers. The mean value of advising students per each faculty is 2.84 with the standard deviation of 1.39. 7 faculty members identified the difficulties to work with undergraduates due to the lack of students who have interests in their specific fields of research and limited interaction with undergraduates due to no teaching courses for them. Based on the survey, 10 students are under research distinction (URS), 6 students are taking research courses

without research distinction, 6 students are research volunteers, and 10 students are undergraduate (UG) researchers paid hourly by projects without any research credit. Faculty members think that 2-3 UG researchers are ideal for their research lab, and a work of around 5-6 hours per week is typical for UG researchers in the lab. It is usual that their UG researchers are working in their lab for around 2-3 semesters.

Discussion

The survey results provided the answer for the research question #1. Undergraduate students participating in research responded that they have sufficient information to involve with research activities and wished to join the research from Sophomore year rather than later years. They expressed they received enough support to pursue their research activities. On the other hand, more than half of students who have not involved in research expressed their interests in participating in research. However, they found several barriers such as finding a faculty member, lack of participating research, and limited time to start research. Considering SCCT, these supports and barriers of participating research may impact undergraduate students' career choice related to research in Civil Engineering field.

To answer research question #2, faculty members' survey results show that the majority of faculty members had two or three UG researchers in their research labs and did not face much challenge to work with UG researchers. In other word, as long as students are in their research team or activities, faculty members were able to provide sufficient support to students for the development of their research competencies. However, a few faculty members perceived that they had challenged to provide proper research training and meaningful projects to UG researchers because of the lack of students' interests in specific research fields and their low levels of knowledge and skills. By applying SCCT, it is arguable that students with lower interests and competencies (or self-efficacy) in research may not pursue their career related to research.

Both faculty members and students indicated a desire for more undergraduate research. Around 15 out of 21 faculty members indicated that they would like to hire more undergraduate researchers in their group. However, they described challenges of limited time to train undergraduates and hiring them with HR. They also felt difficulties with research distinction process and noted that it is not easy for undergraduate students to see the value of research. Undergraduate students also identified obstacles for getting involved in research. They thought that there are limited announcements and information about research opportunities and how to find advisors and start research. More than 70% of students suggested that Civil Engineering website can be improved to find more helpful contents about each research lab and its advisors and see more research opportunities, required time and commitment earlier in their time at the university.

INTERVENTIONS for PROMOTING UNDERGRADUATE RESEARCH

Undergraduate Research Committee (URC) at CE made an action plan for promoting UG Research.

Change the website of CE to provide easy access to undergraduate students

The website of the department has been updated. Various research labs are introduced on the main page, and additional pages are added to provide more information regarding UG research (https://ceg.osu.edu/degrees/undergraduate-research-cege). They provide more resources of research opportunities not only in the department, college, and university but also external agencies and institutions. Students can easily find research opportunities such as fellowships, scholarships, or researcher positions depending on their interests of area, research labs or other institutions or agencies.

Provide a UG Research Expo every year

URC at CE has provided annual UG Research Expo in fall semester since 2018. All levels of UG students were invited to this event, and it took around 45 minutes of presentations by academic advisors and various faculty members. The presentations included undergraduate research options and their benefits, how to get involved in research, how to find advisors, and how to get research credits. There was a Q&A session with a panel of current UG researchers, and one-minute presentations by each research lab was followed to introduce various research topics to students. After all presentations, there was around 15 minutes for students to talk with faculty members in person.

Launch CE Summer Undergraduate Research Fellowships (SURF)

URC at CE discussed about the survey data and made a plan to provide more research opportunities to UG students in the department. The CE Summer Undergraduate Research Fellowship (SURF) program is lunched in early 2020. This program supports undergraduates who have already completed at least one year of research. Since the SURF program of COE supports students for their first research experience, CE SURF program supports undergraduate researchers in their second year of summer for 10 weeks. Their application is similar to the SURF program of COE, but it requires a statement for the research that they have conducted in the department.

Other Practices in other departments of COE at the university.

There was a discussion for promoting undergraduate research in the meeting of undergraduate research committee of COE in 2019. Committee members from all departments of COE shared their methods. Most members noted that their Chair continuously promoted undergraduate research. In the meeting, two interesting methods were introduced, which are described briefly below.

Incentive for Advising Undergraduate Researchers

There are no official metrics to evaluate advising services at the university, but one department of COE made an internal policy to recognize the academic service by faculty members for promoting and engaging in UG Research. They evaluate that the service of advising four

undergraduate researchers is equivalent to the service of advising one Ph.D. student or advising two Master students. During annual faculty evaluations and tenure evaluations in that department, their faculty members can count their advising service with these numbers. This policy further motivated faculty members to advise more undergraduate students. On the other hand, CE does not have a clear evaluation process for advising undergraduate students.

Automated Email System on the Website

One department developed a website for undergraduate students to easily start research and contact faculty members. On the website, students can figure out various research topics and contents in the department. When they find their interests, they can submit them with their basic qualifications. Students can choose topics of interest from one to multiple choices anytime and submit their interest via the website anytime. The website automatically generates brief research applications of the students and send electronic copies to faculty members in related areas via emails. A few faculty members did not like this system due to the amount of emails they received from students, but they agreed that it is a convenient system for students. In addition, faculty members can also post available UG research positions to the same website; these positions are usually paid positions supported by projects.

CONCLUSIONS

This study highlighted the current state of supports and barriers for undergraduate research in the department of Civil Engineering at one institution, which links to the UG students' careers related to research in the same field. Current limitations of the UG research program in the department are discussed, along with current actions and future strategies. Several interventions are explored including; changing the website of Civil Engineering to provide easy access to UG students, providing a UG research expo every year, launching Civil Engineering summer undergraduate research fellowships, offering incentive for advising undergraduate researchers, and launching an automated email system in the website. Several of these interventions have already been implemented in the department. After exploring and implementing these interventions this year, additional surveys and interviews with students and faculty members will be conducted to understand how effectively these interventions promote UG research. Furthermore, using the SCCT framework, career paths of UG students in the department will be evaluated if they are toward research and persistence in civil engineering field.

This study along with the planned future research can provide new insights to the Civil Engineering community on effective institutional and faculty efforts that support UG students to participate in research.

REFERENCES

Bhattacharyya, P., Chan, C. W., & Waraczynski, M. (2018). How Novice Researchers See Themselves Grow. *International Journal for the Scholarship of Teaching and Learning*, *12*(2), 3.

Carpi, A., Ronan, D. M., Falconer, H. M., & Lents, N. H. (2017). Cultivating minority scientists: Undergraduate research increases self-efficacy and career ambitions for under-represented students in STEM. *Journal of Research in Science Teaching*, 54(2), 169–194

Dolan, E. L. (2016). Course-based undergraduate research experiences: Current knowledge and future directions. Natl Res Counc Comm Pap, 1-34.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H. & Wenderoth, M.P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23) 8410–8415.

Kuh, G. D. (2008). Excerpt from high-impact educational practices: What they are, who has access to them, and why they matter. *Association of American Colleges and Universities*, *14*(3), 28-29.

Lent, R. W., Brown, S. D., & Hackett, G. (2002). Social cognitive career theory. Career choice and development, 4, 255-311.

Troy, C., Bruntz, M. J., & Govindaraju, R. S. "Challenges and Opportunities for Recruiting Students to Undergraduate Civil Engineering Programs," *2016 ASEE Annual Conference and Exposition*, June 26-29, 2016, New Orleans, LA.