

BOARD #160: EFFECTIVE MENTORING PRACTICES FOR UNDERGRADUATE RESEARCH

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EFFECTIVE MENTORING PRACTICES FOR UNDERGRADUATE RESEARCH

Abstract

Review Paper: The integration of teaching and research in higher education is a foundation of effective engineering pedagogy, with mentorship playing a pivotal role in this synergy. While involving undergraduate students in research can significantly enhance their educational experience, it also presents unique challenges for faculty members, who lack formal training in mentoring undergraduate research students. Notably, many junior faculty members tend to mentor based on their own experiences as mentees, perpetuating a cycle that may not always reflect best practices, as formal education on research mentoring is rarely provided in academic settings. This research study addresses common hurdles mentors face, including students' inexperience with research methodologies, time management difficulties, and declining motivation over time. Despite these challenges, effective mentorship in undergraduate research offers invaluable opportunities for both students and faculty mentors.

The study highlights the mentor's crucial role not only in guiding project execution but also in fostering essential skills such as scientific rigor, critical thinking, and research independence. Key strategies for impactful mentorship are proposed, including establishing clear expectations, collaborative planning, structured deadlines, research portfolio development, and frequent checkins. Importantly, the research study emphasizes the delicate balance mentors must strike between providing guidance and encouraging student autonomy, allowing mentees to take ownership of their work while offering supportive oversight. By examining mentorship programs across various institutions, this research aims to identify and recommend best practices for integrating meaningful research experiences into undergraduate engineering education. The insights presented contribute to the ongoing discourse on preparing the next generation of engineers through hands-on, mentored research experiences that bridge the gap between classroom learning and real-world application, while also addressing the need for more structured mentorship training for faculty. This review study will be presented in a poster presentation format.

Introduction

Over the last decade, engineering education has seen significant changes, especially with the addition of undergraduate research experiences (UREs) into standard curricula. Research shows that these UREs bring significant advantages for both students and the faculty involved. Faculty report benefits like enhanced professional development, greater job satisfaction, expanded networks, and recognition for developing talents [1, 2, 3]. Students show improvements in their technical knowledge and communication skills, gain more professional confidence, and feel better prepared for their future careers [1, 3]. UREs create a platform for applying theoretical knowledge to real-world challenges and encourage students to refine their skills, which in turn bolsters their

confidence and overall growth. Additionally, these experiences offer opportunities for networking with leaders in research. Mentorship often plays a pivotal role in improving retention and graduation rates, helping students secure job positions or gain admission to graduate programs, giving them an advantage over others [1, 2, 3].

Current literature describes undergraduate research mentoring as a two-way relationship where faculty take on various roles like guide, role model, teacher, and sponsor. Johnson [4] points out that successful mentors offer support in many areas, including sharing technical knowledge, providing career advice, and creating development opportunities. Similarly, a study performed by Brew [5] explains that effective mentoring starts with recognizing students' strengths and interests, followed by offering structured guidance on research methods and professional growth.

Source of Undergraduate Mentorship Experiences

The progression of mentorship experiences and their impact on student success has been extensively documented through surveys. Data from the 2018 Strada Education Network and Gallup survey indicates that 25% of college students strongly feel they received effective mentorship during their studies - an increase from 20% in 2014. Notably, 64% of the overall student population sees professors as their primary mentors [6]. This finding reinforces the importance of training professors in mentorship since they play a significant role in students' college experience.

The 2018 Gallup survey sheds more light on experiential learning. About 40% of students report engaging in experiential learning, such as internships or research, which allows them to apply what they learn to open-ended, real-world problems. Among these students, 24% reported that they worked on their projects for at least a full semester [6]. UREs generally take place during students' junior and senior years when they have acquired stronger technical skills. The Strada Gallup study also found that 60% of those involved in these projects were upperclassmen (21% juniors and 39% seniors), while only 10% freshmen participated in semester-long projects [6].

Mentoring Programs

Recognizing the value of early URE involvement, many colleges have started programs to motivate first- and second-year students to engage in undergraduate research. Most of these programs provide mentoring support and guidance to both students and faculty. Figure 1 summarizes the key contributors to a successful mentoring program including peer mentors, faculty mentors, and institutional resources. Most institutions with effective undergraduate programs incorporate some combination of these key contributors. The Penn Undergraduate Research Mentoring Program (PURM) [7] is a great example that focuses on fostering strong mentor-mentee connections. PURM offers summer research opportunities for first- and second-year students under the guidance of a Penn research faculty. The program equips students with the necessary skills through workshops on data management, Python programming, data analysis, and visualization. Participants also receive training in networking, public speaking, presentation skills,

and research ethics. As an additional resource, there are research peer advisors (RPAs) from various research fields like engineering and sciences, business, language studies, arts, etc. RPAs provide support in getting students started in research including exploring research opportunities, identifying potential faculty mentors, and applying for research grants [7].

The Undergraduate Research Opportunity Program (UROP) [8] at the University of Michigan supports research collaborations between undergraduate students and faculty. The first and second-year students work on a year-long URE and attend mandatory research seminars on resume and cover letter writing, foundational research concepts, and the impact of research on our communities and the world. UROP supports all academic disciplines, including the humanities and creative arts, social sciences, natural and biomedical sciences, environmental sciences, and physical sciences and engineering. In 2017, UROP conducted a survey to assess the success of the program and their results show that the UROP has positive effects on retention, academics, attitudes, and educational and professional activities after graduation [8].

Northern Arizona University offers the Research Assistant Mentoring Program (RAMP) [9]. The primary goals of RAMP are to support and prepare undergraduate students for UREs and provide workshops and training on several key areas. Topics include how to conduct and design research, field and lab safety, communication skill development, interpretation of scientific literature, professional skills, teamwork and leadership, quantitative skills, data collection, and data management [9].



FIGURE 1: Key contributors to a successful mentoring program.

There are also peer mentoring programs available. Many of these programs are tailored to help incoming students get involved with research early. For example, the Office of Undergraduate Research (OUR) peer mentor (PM) program [10] at the University of Nevada is a year-long program that pairs freshmen with students who have prior research experience. OUR PM has virtual research readiness workshops on lab safety, writing a research paper, and preparing an effective poster presentation [10]. Similarly, Kennesaw State University (KSU) has a peer ambassador program [11] to support UREs. They work with students who are accepted to the firstyear scholars' program. The first-year scholars program pairs first-year students with faculty members in a research field students are passionate about. At KSU, peer ambassadors hold office hours, regular meetings, and check-ins with mentees, and offer guidance on writing an abstract, preparing a poster, and presenting at conferences [11]. Other examples of peer mentoring programs include the Cornell Undergraduate Research Board (CURB) Peer Mentorship Program at Cornell University [12] and The Girls Excelling in Math and Science (GEMS) [13] program at the University of Central Florida.

Challenges in Undergraduate Research Mentorship

Implementing undergraduate research mentorship presents significant challenges for both faculty and students. Research by Johnson et al. [2] and Lunsford et al. [14] suggests that not all college professors are equipped with the right mindset or skills to be effective mentors, especially if they lack mentoring during their graduate training. Faculty members face numerous obstacles while mentoring. Baker et al. [15] point out that many institutions don't allow course release time for professors juggling multiple undergraduate projects. This leads them to balance advising capstone projects and several research experiences alongside teaching and other responsibilities. A study by Baker et al. [16], gathering insights from faculty focus groups at five institutions, revealed that mentoring undergraduate research seldom contributes significantly to tenure and promotion processes. Other challenges include inadequate training in research mentoring, issues with time management, burnout, lowered productivity, and limited funding for research [16, 2].

Most institutions don't have any mentor training program as part of their graduate studies. However, mentor training is essential to overcome some of the challenges listed above. The California Institute of Technology offers a series of undergraduate research mentoring workshops and panel discussions specific to faculty members during the summer. Example topics include how to launch the project and set expectations, effective communication tools, giving and receiving feedback, motivating students, and developing a positive science identity [17].

Students also encounter their own set of challenges in undergraduate research. Recent research by Baker et al. [3] at Albion College highlighted the top three concerns among students: clarity of faculty expectations, consistency of experiences, and time management. Many students struggle to juggle their responsibilities among busy class schedules while engaging in research. Additional hurdles include limited access to mentors, financial constraints, and inconsistent opportunities for engagement throughout their academic journey [2, 3]. However, mentoring programs like PURM [7], UROP [8], RAMP [9], OUR PM [10], CURB [12] and GEMS [13] initiated by many universities are providing essential resources and support to first and second-year students during their research experiences.

Effective Mentoring Practices

Research into effective mentoring practices reveals that successful mentoring programs share key components, including structured training for both faculty mentors and students along with adequate resources including funding and research space. In the current study, the process of implementing effective mentorship is broken down into planning and execution phases.

During UR mentoring, faculty mentors are involved in a broad range of activities, as noted by Brace et al. [18]. These include setting project expectations and timelines, introducing students to laboratory settings, discussing career opportunities, managing resources, teaching scientific research methods, holding weekly progress meetings, guiding students to prepare presentations, writing conference papers and reports, and connecting students with other scientists [18].

<u>Planning Phase</u> This phase revolves around project planning that aligns students of varying abilities and experiences with appropriate projects. It involves defining key aspects related to the research project: goals, specifications, and learning activities. Constructing UR projects that are effective, realistic, and feasible can be challenging. Laursen et al. [19] identified four essential traits of fruitful undergraduate research projects:

- The project should suit students' theoretical skills, years in school, and background knowledge.
- The scope of the project needs to be flexible enough to expand or simplify according to the student's progress.
- Projects should utilize skills students already have or can quickly acquire so they can make meaningful strides during the project timeline.
- The project's scope should be structured to provide a reasonable chance of achieving results.

Execution Phase During the execution phase, faculty interacts with students regularly to accomplish the UR project goals. Effective practices that could be implemented during this phase are as follows:

- Having Clear Communication and Well-Defined Scaffolded Expectations: Ensure students fully understand project goals and expectations; keep lines of communication open among all team members; give regular feedback and updates on progress [20, 21]. Mentor-mentee contracts are a great way to reinforce clarity. The contract serves as a tool to assist faculty mentors with mentee selection and expectation setting prior to research. Mabrouk [22] outlines essential elements of mentoring contracts and provides samples.
- Promoting Skill Development Opportunities: Encourage technical and scientific growth; provide chances to participate in conferences; guide students through co-authoring scientific papers; assist with poster presentations [23, 24, 25, 26].
- Balancing of Guidance and Independence: Provide direction through one-on-one regularly scheduled meetings while allowing students to solve problems independently; promote self-directed learning by providing resources; and support decision-making while keeping the project on track. [27]

- Building a Supporting Learning Environment: Cultivate a positive and encouraging research environment, maintain an accessible and passionate faculty mentor presence, implement clear guidance, and offer networking opportunities with other researchers or industry professionals. Facilitating connections with professionals in the field can greatly broaden students' career perspectives and boost their self-esteem especially first and second-year students. Creating a positive learning atmosphere is vital for successful UREs. This involves building a community among team members and nurturing open discussions. Bender et al. [28] provide examples of activities that facilitate a community such as organizing field trips, playing sports and games, attending professional events, etc. Faculty should strive to maintain an enthusiastic and approachable attitude [24].
- Providing Meaningful Timely Feedback and Assessment: Mentors should ensure that there are effective structures for feedback and assessment throughout the execution of the UR project.

Ultimately, the success of undergraduate research mentorship programs greatly relies on institutional support. These initiatives require comprehensive faculty and student mentorship development programs and strong support systems. Faculty members must have opportunities for formal mentoring training to enhance their effectiveness in guiding students.

Conclusions

Several key recommendations emerge that are aimed at enhancing undergraduate research mentorship in engineering education. Institutions must provide comprehensive faculty development programs that cover both the technical and interpersonal sides of research mentorship. These programs should include training in effective communication and undergraduate research mentoring methods. Getting first and second-year students involved early on is especially beneficial for building solid research skills and keeping students engaged. Creating peer mentoring networks could also make a big difference, offering additional support and guidance for students. Regularly assessing these mentorship development programs is crucial to identify areas for improvement and ensure that mentorship initiatives align with the needs of students, faculty mentors, and the mission and vision of the institution.

The review of previous studies highlights how important effective mentorship is during undergraduate research experiences (UREs). Developing a successful mentoring program that supports all the stakeholders requires a coordinated approach. It requires an in-depth understanding of the needs and culture of the institution. Moving forward, this research study aims to develop standardized assessment tools for mentorship programs and explore the long-term effects on students' success in their chosen careers.

The views and opinions expressed herein are those of the author and do not purport to state or reflect the position of the United States Government or any agency thereof, including the United States Military Academy, the Department of the Army, or the Department of Defense.

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