PURM
Perspectives on Undergraduate Research & Mentoring

Cultivating academic self-efficacy and student engagement for undergraduate students through research experiences and student-faculty interaction

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Introduction
To maximize research experiences for students, research programs and structures to promote academic self-efficacy and engagement must be fostered with intentionality. A key ingredient of student success is enhanced student-faculty interaction. As Trujillo et al. (2015) noted, "the practice and perpetuation of scientific research requires that incumbent scientists train junior investigators" (p. 1). Hall et al. (2017) have observed that undergraduate research (UR) provides an important opportunity for faculty to foster mentoring skills, pursue academic interests, collaborate with peers, and "interact with students in a different context" (p. 4). Teams focused on both building STEM research capacity and developing skills to thrive as scholars in a new context sought to cultivate academic self-efficacy through summer research experiences at two different institutions. Anchored on the key ingredient of student-faculty interaction, both programs sought to enhance student outcomes through cultivating academic self-efficacy and student engagement.

Research strongly suggests that student-faculty interactions positively relate to student learning outcomes (Beckowski, & Gebauer, 2018; Cotten & Wilson, 2006; Cox & Orehovec, 2007; Kim & Sax, 2014; Kuh & Hu, 2001; Pascarella & Terenzini, 1991; Trolian et al., 2016; Umbach & Wawrzynski, 2005). Previous scholarship provides different ways of conceptualizing these interactions. For example, Cox and Orehovec (2007) categorize the frequency of student-faculty interactions in the form of a pyramid in which interaction ranges from very infrequent (Disengaged) to very frequent (Mentoring). Other studies differentiate between specific types of student-faculty interactions, wherein interactions are described as social or substantive (Kuh & Hu, 2001), casual or substantive (Reason et al., 2010), incidental or functional (Mara & Mara, 2010), and informal or formal (Cotten & Wilson, 2006). Mara and Mara (2010) divide student-faculty interactions into purposeful opportunities, programming plans, and happenstance interactions. Similarly, Cole (2010) suggests that interactions can include course-related contact, active seeking of criticism or advice, and mentoring relationships. Sriram et al. conceptualize student-faculty interaction as academic, social, or deeper life, with deeper life interactions focusing on meaning-making, values, and purpose (McLevain Overton & Sriram, 2024; Sriram & Erck, 2022; Sriram et al., 2020).

This article provides insights from two collaborative efforts focused on a research experience for undergraduate (REU) design that were each framed to cultivate academic self-efficacy in a new research setting, foster student engagement, and to create student-faculty interactions that sought to bring new meaning to the students' sense of scholarly identity. This work builds off a previously established effort at UNCW (Grove et al., 2023) that has continued to further develop and provide a collaborative example to a new effort at Baylor University.

Context

Baylor University is a private Christian university in central Texas that is a Carnegie Research 1 (R1) university classified as a doctoral institution with "very high research activity" (Baylor University, 2024). Baylor has approximately 15,000 undergraduates and 5,000 graduate students. Through its research and scholarship, Baylor seeks to address the "world's most meaningful challenges" and has a distinct mission "to educate men and women for worldwide leadership and service by integrating academic excellence and Christian commitment within a caring community" (Baylor University, 2024a). In its most recent strategic plan, Baylor seeks "to grow its enrollment and research endeavors specifically in the areas of health, engineering and applied sciences to have a voice of influence in solving global challenges" (Baylor, 2024b, p. 3.)

The University of North Carolina Wilmington (UNCW) is a regional coastal university of nearly 20,000 students, most of whom are undergraduates. Two key priorities in UNCW's strategic plan include "lead in interdisciplinary teaching and learning" and "expand regionally relevant/globally important research" (UNCW, 2024a). UNCW is designated as a Carnegie Research 2 (R2) "doctoral university with high research activity, much of it centered in marine-related sciences" (UNCW, 2024b). For example, major research program areas include ocean color and nanosatellite study, a marine mammal stranding program, an undersea vehicles program, a shellfish research hatchery, and a focus on monitoring water quality in the Cape Fear River estuary.

Literature Review

Student-Faculty Interaction and Associated Learning Outcomes

Gaff (1973) followed some of the early research on student-faculty interactions (e.g., Jacob, 1957; Feldman & Newcomb, 1969) with a longitudinal study using survey data from students and faculty at nine institutions. Although teaching is a hallmark of the faculty profession, Gaff's research is one of the earliest studies empirically demonstrating the importance of student-faculty interactions outside of the classroom. Results from students nominating "outstanding teachers" demonstrated that the most significant difference between faculty who were nominated and those who were not was the extent of interaction that occurred outside of class. Furthermore, nominated faculty reported higher rates of meaningful interaction compared to colleagues who were not nominated. This work extended the line of inquiry on student-faculty interaction away from frequency and towards quality and predictors. For example, Endo and Harpel (1982) found that informal student-faculty interactions can have a stronger influence on outcomes than formal interactions.

Student-faculty interaction has been empirically linked to increased academic motivation (Komarraju, Musulkin, & Bhattacharya, 2010; Trolian et al., 2016), cooperation among peers (Garrett & Zabriskie, 2003), commitment to the institution (Schreiner, Noel, Anderson, & Cantwell, 2011), openness to diversity (Reason, Cox, Lutovsky Quaye, & Terenzini, 2010), and self-concept and self-worth (Cotten & Wilson, 2006). Such outcomes demonstrate the importance of student-faculty interactions for mentoring relationships. Examining student-faculty interaction in the 1990s from more than 5,000 students at 126 institutions, Kuh and Huh (2001) found that most students experienced little contact with faculty outside of the classroom, and that when students did interact with faculty outside of class, it was to clarify class content. They also found that student-faculty interaction increased over a student's four years in college. Notably, Kuh and Hu (2001) differentiated between substantive and social interactions between students and faculty, suggesting that substantive interactions have a more meaningful impact on student satisfaction and overall experience. They advocate that institutions should devote resources to substantive forms of student-faculty interaction, including faculty-supervised internships, capstone experiences, faculty-moderated discussions, and undergraduate research mentorship experiences.

There is a tension between breadth and depth in student-faculty interaction. Breadth allows for reaching more students, but depth of interactions provides the greatest positive impact for students. Student-faculty interaction can be broadly divided into formal and informal types. Garrett and Zabriskie (2003) analyzed the quality of student-faculty interactions within living-learning programs across two broad categories: (1) formal-academic interactions and (2) informal-mentor interactions. They found that living-learning programs were successful in their attempt to create out-of-class student-faculty interactions, both in the formal-academic and informal-mentor categories. However, though student-faculty interaction was higher in residential communities with living-learning programs than in residential communities without such programs, Garrett and Zabriskie (2003) noted that, overall, out-of-class interaction between students and faculty was still very low, with the majority of students admitting that they only engaged in activities in the "informal-mentor" category "a few times a semester" (p. 43). These findings suggest that while living-learning programs may be successful in creating structures for student-faculty interactions to occur, more effort is needed to increase both student and faculty buy-in so that such structures accomplish their goals. Other complimentary programs, such as research mentoring programs, can allow for greater depth in student-faculty interaction.

Faculty as Key Players on a Collaborative Continuum

Cotten and Wilson (2006) stress the need for research aimed at understanding the factors that evoke interaction between faculty and students. Most notably, Umbach and Wawrzynski (2005) found that faculty were instrumental in creating a culture that emphasized student learning outcomes, and that student perceptions of gains increased when faculty emphasized best practices. They concluded, "We found that faculty behaviors and attitudes affect students profoundly, which suggests that faculty members may play the single-most important role in student learning" (p. 176). Similarly to other scholars (Cotten & Wilson, 2006; Garrett & Zabriskie, 2003; Kuh & Hu, 2001), Fuentes et al. (2014) conceptualize student-faculty mentoring relationships in two distinct categories, formal mentoring, and informal mentoring. Formal mentoring refers to in-class interactions and informal mentoring refers to out-of-class interactions. They suggest that informal mentoring between students and faculty contributes more meaningfully to learning outcomes than does formal mentoring and that a culture of mentoring relationships between students and faculty is created through the socialization of students into the academy.

Employing a factor analysis technique, Cole (2007) categorized 15 student-faculty interaction-related measures into three distinct groups: course-related faculty contact, advice establishing a mentoring faculty relationship. Course-related contact entails exchanges such as advice on coursework or seeking course information. Advice and criticism are represented in academic conversations over direct feedback of assignments. Mentoring relationships occur through faculty-led research projects or cocurricular engagement, such as visiting a professor's house for a meal. Assessing these groupings led Cole to posit that mentoring relationships positively influence academic outcomes. Similarly, Crisp and Cruz (2009) articulate that "overall, findings have been positive and have indicated a positive relationship or an impact of mentoring on student persistence and /or grade point average of undergraduate students" (p. 532). Further, Cole and Griffin (2013) articulate that many student-faculty interaction studies show their frequent positive effects on GPA, intellectual self-concept, learning, cognition, well-being, and positive attitude toward literacy.

Cox and Orehovec (2007) produced a typology of student-faculty interactions that specifies a fluid, contextually influenced continuum (in descending order of observed frequency): disengagement, incidental contact, functional interaction, personal interaction, and mentoring. Disengagement characterizes an essential absence of cocurricular faculty connection. While faculty and students may be present around each other, disengagement is represented by an apathetic or oblivious response to such presence by both parties. On the other end of the continuum, which was the least observed and most difficult to define, was mentoring. Mentoring focuses not on a program or structure, but on the close relationships students form with faculty. Ironically, Cox and Orehovec (2007) noted that even though few students mentioned having such mentoring relationships, faculty often viewed themselves as mentors.

The Importance of Academic Self-Efficacy and Mentoring in STEM Fields

Mentoring undergraduate students in the STEM fields provides aspiring professionals with beneficial guidance, support, access to real-world applications, and opportunities to map out career paths. In recent years, there has been an increasing emphasis to involve undergraduate students in research with leading researchers in higher education institutions to support talent development and to foster their persistence in STEM careers (Gentile, Brenner, & Stephens, 2017; Estrada, Hernandez, & Schultz, 2018). In 1978, the Council for Undergraduate Research was established to advocate for the value of research conducted by undergraduate students and to provide practical advice for mentorship (Council on Undergraduate Research, n.d.). This organization emphasizes the importance of the mentoring relationship rather than the scholarly inquiry's structure or even the experience's intellectual content for undergraduate researchers.

In a foundational study, Chemers et al. (2001) found that academic self-efficacy strongly related to performance and adjustment for college students, both through directly influencing academics and indirectly influencing coping mechanisms. They define academic self-efficacy as students' "confidence in their ability to perform well academically" (Chemers et al., 2001, p. 58-59). Scholars have found that academic self-efficacy positively influences academic performance, persistence, accumulated credits, and academic motivation (Chemers et al., 2001; Multon et al., 1991; Schunk, 1991; Zajacova et al., 2005)

STEM research mentors serve as role models and can provide important connections to information and resources that support undergraduate researchers in ways that can further develop their research skills (Asif, Edison, & Dolan, 2023). Ravishankar, et al (2024) showed that effective mentorship can enhance an undergraduate students' sense of belonging, science identity, and science efficacy, which all contribute to retention and persistence in pursuing a STEM career. Kim and Sax (2014) not only found that student-faculty interactions were strongly predictive of academic self-efficacy, but they also found that the influences can vary by major. Their research found that students in artistic fields tended to receive more student-faculty interaction and mentoring than students in other disciplines. Therefore, STEM students may be less likely to receive the kinds of student-faculty interaction that improve academic self-efficacy in students. An effective STEM mentor maintains a supportive community environment with high expectations for scientific conduct and allows the undergraduate student to observe the iterative process of research with real-time problem-solving and critical thinking (Munroe, 2023). When undergraduate students are embedded withing the research program of a faculty mentor, there is the potential to form research teams, where these students can engage with others to develop interpersonal skills to work as part of a team (Ng & Hagen, 2015). Effective mentoring of undergraduate students in STEM cultivates individual growth and strengthens the broader scientific community by fostering collaboration and innovation.

Overview of the Research Experiences Projects for Undergraduate Students

The UNCW REU effort involved a wide range of research projects associated with marine science, and was facilitated by the Center for Support of Undergraduate Research (CSURF) and the Office of the Associate Dean for Student Success and Applied Learning In introductory interactive presentations, the first-year students described how they would study predator and prey interactions using GoPro technology; monitor tide sensors; examine strains of seagrass and interactions to their environment; study snail behavior; measure lake sediments; investigate the effects of waves, water temperature, and stratification; examine temperature effects on seagrass; study variations of copepod orientation and predation; and examine the anti-inflammatory effects of brevenal compounds on human monocyte cells (see Grove et al., 2023).

REU students had the opportunity to work on projects that focused on developing low-cost water sensors; the synthesis of marine-based and cannabinoid compounds for exploration as potential medicinal agents; aquatic copepods; and the role that current and future climate change plays in the health and resiliency of seagrasses. Such interdisciplinary projects involved faculty in UNCW's Departments of Biology and Marine Biology, Chemistry, Computer Science, Earth and Ocean Sciences, and Physics and Physical Oceanography (Grove et al., 2023).

REU students, their faculty mentors, and often other research teammates worked closely together in lab and field settings over the ten-week summer program. The REU students were the owners of work product activities such as creating research posters that provided a scholarly overview of their project's objectives, research questions and respective methodology, results, and conclusions as a final summative activity. The researchers have noted (Grove et al., 2023) that the discussions both between the first-year students and their mentors and between themselves as a cohort facilitated by the principal investigators helped broaden their understanding of the lab and field work, through all stages of the research process. Additional attention was spent on professional development activities including how to best incorporate their research into their CVs and practicing how to communicate their research to non-specialists.

The Baylor project was anchored in the Baylor Point-of-Needs-Innovation (PONI) center which seeks to "transform traditional supply chains by developing on-demand material and manufacturing solutions at the location of use through a circular economic approach" (Baylor University, 2024c). Focus areas include robotics, manufacturing, advanced materials, and aerospace-related projects. The project was modeled after the REU concept as members of the project team had collaborated on REU projects at prior institutions.

Ten undergraduate scholars from institutions ranging from Puerto Rico to Virginia to Texas spent 10 weeks on Baylor's campus working with PONI-affiliated faculty and graduate mentors. Five key projects allowed teams of about two students each to collaborate on a specific project and share insights and findings throughout the ten-week experience with the larger group. Like the UNCW format, all scholars met weekly with members of the larger REU team where education professors and engineering professors helped them focus on learning outcomes. Their projects ranged from working with additive friction stir deposition machines to upcycle scrap builds, to sustainable recycling of secondary aluminum alloy feedstocks through low-power hybrid manufacturing, and from defect identification of additively manufactured lunar regolith composites for in-space manufacturing (ISM) to visualization of multimodal materials science data for sustainable hybrid manufacturing using mixed reality.

The mentors and undergraduate students engaged in their respective research projects in the Baylor engineering lab and reported weekly updates in an engineering learning setting. They also met weekly in an education-faculty-hosted setting to work through a book study focused on developing talent (Coyle, 2009). Topics ranged from cultivating research skills to focusing on goals throughout one's collegiate experience. Throughout the ten weeks, they also honed communication skills, partnering with the university museum educators in an outreach-focused project. Through a "Meet the Scientist" forum, they learned over a four-week training period how to communicate a complicated scientific idea to a general audience, and then spent a day in a structured museum setting interacting with K-8 students to convey what they had learned that summer in a hands-on engaging activity, such as building a rocket or learning programming code. The challenge was to determine important "entry points" of engagement depending on the age group, and how to effectively communicate through appropriate vocabulary and level of interest.

Evaluative Findings

For this article, both universities wanted to build off a program evaluation for the student experiences at both universities that consisted of piloting a pre- and post-survey and examining student work products (Grove et al., 2023). The pre-and post-surveys blended and modified questions from the *Student Attitudes Toward STEM Survey* (Friday Institute for Educational Innovation, 2012) and the *STEM Transfer Model* (Wang, 2017) to create a new instrument designed for the REU experience, as initiated at UNCW, in which the pilot survey instrument was designed to gather student feedback in areas including STEM content interests; STEM career interests; confidence and efficacy in STEM coursework and tasks; perceived value of mentoring; and perceived confidence in future applications related to STEM (Grove et al, 2023). As Table 1 and Table 2 show, there were increases in math confidence, math enjoyment, science confidence, science enjoyment, communication skills, and engineering interest. The pre-and post-test differences in science enjoyment and engineering interest were statistically significant with large effect sizes. Although the samples were small, the data suggest the mentoring programs had positive influences on the participants in terms of confidence, enjoyment, communication skills, and interest in engineering.

Table 1. *Pre and Post Data from REU Student Surveys from Baylor University*

Scale	Baylor Math Confidence	Baylor Math Enjoyment	Baylor Science Confidence	Baylor Science Enjoyment	Baylor Communicatio n Skills	Baylor Engineering Interest	Baylor Future Application
# of Items	14	3	13	2	4	1	5
Cronbach's Alpha	0.903	0.771	0.916	0.681	0.723	N/A	0.883
McDonald's Omega	0.896	0.813	0.907	N/A	0.734	N/A	0.916
Pretest Mean	4.12	4.04	4.31	3.94	4.03	3.56	3.84
Posttest Mean	4.21	4.22	4.40	4.39	4.14	3.78	4.29
Mean Difference	0.09	0.18	0.09	0.44	0.11	0.22	0.45
Statistical Significance?	No	No	No	Yes	No	Yes	No
Cohen's D				0.63		0.44	0.51

Table 2. *Pre and Post Data from REU Student Surveys from the University of North Carolina Wilmington*

Scale	UNCW Math Confidence	UNCW Math Enjoyment	UNCW Science Confidence	UNCW Science Enjoyment	UNCW Communication Skills	UNCW Engineering Interest	UNCW Future Application
# of Items	14	2	13	3	4	1	5
Cronbach's Alpha	0.891	0.635	0.862	0.737	0.877	0.850	0.818
McDonald's Omega	*	*	0.901	0.759	0.886	*	0.800
Pretest Mean	3.49	2.75	4.55	3.67	3.93	1.38	3.73
Posttest Mean	3.59	2.94	4.40	3.83	4.19	1.62	4.45
Mean Difference	0.10	0.19	-0.15	0.16	0.26	0.24	0.72
Statistical Significance?	No	No	No	No	No	No	Yes
Cohen's D						0.39	0.92

Conclusion and Recommendations

These two multidisciplinary research efforts spanned both the sciences and education, with faculty from both areas working to foster a strong faculty-student mentoring program that bolstered scientific research skills while also honing educational and communication skills. Through seeking to bolster the lived, on-campus experiences that Garrett and Zabriskie (2003) noted were typically low, these two programs were anchored in consistent faculty-student interactions with clear goals and desired outcomes identified. Three key findings were identified by our research teams that help illuminate a path forward for undergraduate research mentoring:

1. Intentionality in living and learning space—Whereas the UNCW-based team relied on the coastal setting to emphasize learning experiences that aligned with the marine focus, the Texas-based Baylor team similarly embraced its locality in designing on and off-campus experiences to spark the interest of the undergraduate scholars. In terms of on-campus, students lived together in a residential community with study rooms, lounges, and a community center for activities. The students enjoyed full access to campus facilities and recreational activities. For off-campus activities, students enjoyed activities ranging from the highly structured and aligned to the facilitated yet loosely coupled. Regarding the former, for example, Baylor students toured Lockheed Martin, a leading aerospace and defense company that builds the F-35 Lightning II fighter jet, as well as SpaceX, a company that builds fully reusable space launch vehicles. Regarding the latter, principal investigators and faculty leads engaged students in activities such as coordinating group surf lessons with campus recreation and hosting them at a faculty member's home for dinner and games, which allowed time and space for interaction outside of the classroom to thus counter the typical lack of student-faculty classroom observed outside of the classroom (Kuh & Huh, 2001). Some activities focused on social community, and others focused on substantive formation. For example, students and faculty met one night a week to read through a book discussing talent development. Planning outdoor activities and local field trips helped acquaint the undergraduate researcher with a sense of belonging and plan for future next steps.

2. Involving the greater community to enhance voice and outreach- Working with the university museum educators at Baylor University, the undergraduate researchers had the opportunity to further develop their communication skills to more effectively communicate their research for

different purposes. An earlier cohort at UNCW did the same at a Laboratory School. Through discussions and engaging activities, the undergraduate researchers learned more about how they could communicate their research to a more general audience that might help them secure funding, prepare applications to graduate school, seek employment, or share with community. Additionally, an intentional effort to engage with elementary-school students created positive feedback loops to the undergraduate researchers and provided early-adult role models and social liking opportunities to help expand the STEM K-16 pipeline. One of the authors who visited Baylor's UR experience noted that employing the university museum educators may have improved efficacy due to organizational alignment advantages.

3. Seeking to understand student perspectives- The pre-program survey provided the demographics and characteristics of the students to plan experiences. Students came from various STEM majors, geographic locations, community colleges, and four-year schools. The survey examined the qualities of instruction students received at their native institution whereas the post-program survey (i.e., exit survey) survey mirrored and served as a comparative and evaluative measurement to determine how the REU experience enhanced STEM learning and informed future REU experiences. Training the next generation of laboratory-based research scientists, industry engineers, university faculty, or secondary teachers or principals, benefits from collaboration and dialogue across interdisciplinary fields spanning the sciences and education. Intentionality in mentorships allows for further development of communication skills as well as goal-setting discussions (Sterrett et al. 2018). Being able to understand student perspectives and aspirations enables greater authenticity in shared learning experiences. Being intentional about recruiting, supporting, and listening to students who are typically underrepresented provides important perspective for the learning communities and enriches the learning environment (DeVita et al., 2020).

As Kuh (1995) noted, powerful "out-of-class experiences influence student learning and personal development" (p. 124). This powerful truth from yesterday helps us to continue to illuminate our path forward. When STEM faculty and education faculty work together to engage students in a summer immersion program focused on research experiences and engaging in the learning environment, students benefit from a sharper focus on their scholarly potential and their identity as researchers. From marine sciences to engineering fields, students will gain from being mentored by faculty and learning amongst peers who are similarly immersed in impactful learning experiences. Indeed, the next generation of materials science engineers, marine biologists, high school chemistry teachers, middle school principals, and university professors will benefit from working together, finding common language, and creating synergy to realize shared goals that benefit many students across institutions. Increased confidence and yes, joy, abounds from time spent in these collaborative research spaces.

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