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Mentoring Undergraduate Research in Statistics: Reaping the Benefits and Overcoming the Barriers

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Abstract

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active learning, faculty survey, high-impact teaching practices, recruitment and retention, statistics education, undergraduate statistics research

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Mentoring Undergraduate Research in Statistics: Reaping the Benefits and Overcoming the Barriers

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ABSTRACT

Undergraduate research experiences (UREs), whether within the context of a mentor-mentee experience or a classroom framework, represent an excellent opportunity to expose students to the independent scholarship model. The high impact of undergraduate research has received recent attention in the context of STEM disciplines. Reflecting a 2017 survey of statistics faculty, this article examines the perceived benefits of UREs, as well as barriers to the incorporation of UREs, specifically within the field of statistics. Viewpoints of students, faculty mentors, and institutions are investigated. Further, the article offers several strategies for leveraging characteristics unique to the field of statistics to overcome barriers and thereby provide greater opportunity for undergraduate statistics students to gain research experience.

KEYWORDS

Active learning; Faculty survey; High-impact teaching practices; Recruitment and retention; Statistics education; Undergraduate statistics research

1. Introduction

In their seminal paper, Chickering and Gamson (1987) offered seven principles for the improvement of undergraduate education in colleges and universities. They identified as paramount that good practice in undergraduate education encourages contact between students and faculty. In particular, they state that "frequent student-faculty contact in and out of classes is the most important factor in student motivation and involvement," and that "knowing a few faculty members well enhances students' intellectual commitment and encourages them to think about their own values and future plans." Moreover, Chickering and Gamson (1987) advocated that undergraduate education should encourage active learning; that "learning is not a spectator sport," and students "must talk about what they are learning, write about it, relate it to past experiences and apply it to their daily lives." More recent work has substantiated that these principles are still very relevant today (e.g., Wood and Gentile 2003; Gibbs and Simpson 2005; Mervis 2010; Seifert et al. 2010; Jensen, Kummer, and Godoy 2015; Kilgo, Sheets, and Pascarella 2015). Through this lens, undergraduate research experiences (UREs) must be highly valued as they frequently involve close contact with a faculty mentor and are intimately about students learning through doing. In undergraduate statistics education, these ideas seem particularly important. Research often involves connecting with a diverse set of external disciplines. Such integrated experience is also largely valued by employers. Our explorations revealed that UREs in statistics are not ubiquitous. As statistics educators having continual involvement in providing UREs, we sought to learn more about the reasons for this reality from our community.

In this article, we report the results of a survey about UREs distributed to statistics faculty members employed at a variety of different institution types. We discuss the findings gleaned from survey responses, and the broader perceived benefits of, and barriers to, conducting research with undergraduate students. We provide a synopsis of possible pathways for overcoming the most common barriers encountered by faculty members. Our work can be viewed as a first step toward starting a deeper national conversation on the role UREs should occupy in statistics education. If UREs are sufficiently valued, then incentive structures should align with this value and, to the extent that they do not align, efforts must be made to find solutions that are palatable to three primary stakeholders: students, faculty, and institutions of higher education.

1.1. Background Literature

While discipline focused literature on UREs in statistics is sparse, related literature in STEM disciplines suggests a multitude of advantages to be gained from them. Denofrio et al. (2007) reported on a course for chemistry and biology students that aims to strengthen the link between students' interests and science curricula. Assessment via a pre/post survey demonstrated that self-reports of learning gains are higher among students participating in the course as compared to a reference cohort. Eagan et al. (2013) analyzed longitudinal data on aspiring STEM majors who completed the 2004 Freshman Survey and 2008 College Senior Survey to assess how participation in UREs affects STEM students' intentions to enroll in graduate school. This is of particular importance given the investments

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made by the NIH and NSF in undergraduate research programs with the goal of retaining students in STEM disciplines and facilitating their aspirations for graduate work. Importantly, the authors address several of the shortcomings present in previous research. For example, many prior studies use simple comparisons between undergraduate research participants and nonparticipants, but do not account for the selection bias that may result from the nonrandom decision to participate in URE programs. Eagan et al. (2013) addressed this issue in two ways: using propensity score matching and including a set of controls on precollege, college entry, and college experience covariates. They found a positive association between URE participation and students' probability of indicating plans to enroll in a STEM graduate program that cannot be explained away by other college and precollege characteristics. Although the mechanism for such an impact is not entirely clear, undergraduate research programs may improve students' likelihood of developing post-baccalaureate degree aspirations by providing them with the opportunity to perform as scientists conducting original research rather than "cookbook" labs where the outcome is predetermined. In addition, undergraduate research opportunities provide students with the space to develop the confidence to envision themselves as scientists. These programs may also allow students to see how their work as a scientist can have impacts on communities with which they identify. As Eagan et al. (2013) pointed out, however, their analysis does not allow disentanglement of the effects of different types of UREs.

Evidence of the benefits of UREs for diverse subpopulations of students also exists. O'Donnell et al. (2015) reported on the positive impact of active learning, including undergraduate research, on underrepresented students in the California State University system. Quality mentoring is identified as central to the success of UREs. Students learn technical and research skills from faculty mentors, but they are also socialized into the profession, and build important connections to serve as resources for academic support, professional references, and graduate school preparation (Hunter, Laursen, and Seymour 2007; Laursen et al. 2010). Moreover, it has been reported that traditionally underrepresented students benefit the most from faculty research mentorship (Kinzie et al. 2008; Finley and McNair 2013). More generally, underrepresented minority students, those who enter college with less academic preparation, and first-generation students demonstrate the greatest benefits from UREs (Lopatto 2007; Kinzie et al. 2008; Finley and McNair 2013).

O'Donnell et al. (2015) identified funding for faculty engagement as well as adequate stipends for students as critical components for ongoing success of undergraduate research programs, with 80% of student respondents stating that an adequate stipend was "important" or "very important" in allowing them to participate. The URE should also include aspects related to improvement of communication skills, peer network development, and professional skills training (Hensel 2012). Hathaway, Nagda, and Gregerman (2002) found that students who participated in UREs with activities like career workshops and peer advising were more likely to go on to graduate programs.

There are several shortcomings in the literature that need to be addressed by future work. For instance, Linn et al. (2015) emphasized the need to distinguish between UREs that are not part of a course and which commonly feature carefully selected students, and course-based undergraduate research experiences (CUREs) which typically have a curriculum open to most students. Moreover, Linn et al. (2015) reported that most previous research relies on self-reports of student gains, a poor method for documenting impact, and they call for more rigorous assessments of programs. For example, it is important to account for underlying differences between the different program types since most students in non-course-based UREs are already motivated to succeed in science and may differ systematically from students in CUREs. Even for students in non-course-based UREs, the direction of causality between participation and persistence is unclear: students may not be persisting because of their URE but rather may be participating because of their a priori desire to persist.

Despite extensive literature on the impacts of undergraduate research, most notably in the natural sciences, little has been written on UREs in statistics. Hydorn (2018) did discuss options for helping undergraduate students to develop the skills they need to become practitioners of statistics, and described strategies to help faculty become more effective mentors. Hardin (2017) presented learning goals associated with UREs in statistics. There is also one reported example. Legler et al. (2010) described a year-long seminar in statistics at St. Olaf College that aims to parallel the research process and prepare students for working as part of an interdisciplinary team. Organized through their Center for Interdisciplinary Research (CIR), the seminar exposes students to collaborations with researchers from other disciplines under the supervision of a statistician. This consulting-like model allows students to develop interpersonal communication skills needed for collaborating with clients while working on a genuine, unsolved problem. Students also spend time learning about the subject area from which the problem arose, aim to present their findings at a conference, and produce a manuscript. The CIR led to increased enthusiasm for statistics: from 2005 to 2009, 102 students earned concentrations in statistics and 47 went to statistics-related graduate programs; in comparison, these values were 69 and fewer than 10, respectively, from 1995 to 1999.

1.2. Survey Methods

Our survey of statistics educators regarding undergraduate research was conducted in mid-2017. Volunteer participants were recruited via invitations placed in online community forums hosted by the American Statistical Association (ASA) and the Consortium for the Advancement of Undergraduate Statistics Education (CAUSE). The survey sought to learn more about perceived benefits of undergraduate research from the faculty perspective. It also queried participants to learn more about barriers that may hinder faculty willingness to support undergraduate research. A copy of the survey questions may be found in the Appendix.

For the purpose of the survey, we defined "Undergraduate Research in Statistics" to include any undergraduate student conducting a research project that involved the field of statistics (either methodological or applied), and to include work from summer research, independent research, or senior

capstone projects. We excluded non-capstone class projects that are included as part of regular course work at the introductory or intermediate level, in part based on Auchincloss et al.'s definition, which defines CUREs as involving students in "use of scientific practices, discovery, broader relevance or importance, iteration, and collaboration" (Auchincloss et al. 2014).

There were 120 participants who completed the survey; demographic information for this sample is shown in Table A1 in the Appendix. While we received responses from faculty in different positions and at a variety of institution types, we do not claim that this sample is representative of the statistics education community. This volunteer sample likely has a greater interest in undergraduate research than statistics educators in general. Therefore, any numbers we present here reflect this specific sample and provide us with potential trends in the perceived benefits and barriers among those interested in the topic of undergraduate research in statistics.

Major themes were discerned from the free response answers to the questions "What do you see as the most important barrier(s) of Undergraduate Research in Statistics?" and "What do you see as the most important benefit(s) of Undergraduate Research in Statistics?" These themes guide the discussion in Sections 2 and 3 of this article, while Section 4 provides guidance toward the mitigation of barriers identified in the survey.

2. Benefits

We organize our discussion of the benefits of UREs in statistics according to the most impacted groups: students, faculty members, and the institutions who house them.

2.1. Benefits to Students

Strong undergraduate research programs offer many benefits to statistics students. UREs provide an opportunity for material to be learned beyond the classroom and in more depth; they may help students become more connected to their discipline; they are valued by employers and graduate admissions committees. Such experiences can also often be tailored to the students they seek to train, a flexibility in approach that allows the supervising mentor to maximize their impact.

Our survey identified the following as perceived benefits for students. After each theme, we list how many participants mentioned concepts related to that theme. If a single free text response spanned multiple themes then it was counted as a response for each theme. We also highlight studies that have found similar benefits from STEM UREs. See Table A2 for further summarizations of the student benefits found in the survey responses.

- *S1: Breadth and depth of material* (23 responses). Survey participants valued both the "increased exposure to statistical methods" and the fact that undergraduate research requires a student to undertake "a single endeavor in depth over several months." This is similar to what Lopatto (2010) found in his research on UREs.
- *S2: Skill development* (12 responses). Beyond communication skills, participants mentioned the benefit of improving a wide-range of skills, such as statistical skills, technology skills, and problem-solving skills. Skill enhancement is also a common theme in several previous studies on UREs (Kardash 2000; Mabrouk and Peters 2000; Seymour et al. 2004).
- *S3: Learning by doing statistics* (44 responses). As one survey participant indicated, a URE "gets students thinking critically and creatively about the entire statistical process in ways that textbooks, classroom examples, and limited-scale classroom projects cannot." Many participants used words like "real-world," "open-ended," and "messy data" to express how UREs give students an authentic experience that helps them develop as statisticians. As one participant said, "The projects mimic what one sees in industry. The students have to figure out how to do a complete problem solving cycle." This aligns with Hunter, Laursen, and Seymour's (2007) work on science UREs which highlighted the benefit of "understanding science research through hands-on experience."
- *S4: Communication skills* (15 responses). Through colloquial and conference presentations, as well as manuscript writing, undergraduate researchers in statistics gain experience in communicating results that is not generally a primary component of standard coursework. Several researchers have stressed the importance of integrating training in science communication into the URE (Hensel 2012; Cirino et al. 2017), and Denofrio et al. (2007) reported success in student perceived gains in oral communication from a CURE.
- *S5: Confidence as a statistician* (12 responses). Several survey participants felt that developing confidence in their statistical abilities was the greatest student benefit of undergraduate research. As one respondent put it, UREs give "students experience in 'owning' a research project and working independently to solve it." Likewise, Seymour et al. (2004) and Russell, Hancock, and McCullough (2007) found greater confidence as an emerging scientist to be a perceived benefit among undergraduate students who participated in STEM research.
- *S6: Sense of professional belonging* (29 responses). Many survey responses provided anecdotal evidence that UREs strengthen students' connection to the discipline of statistics. The processes involved expose students to the applicability and relevance of statistics to many fields and help students to see that they can make relevant contributions that benefit society. Seymour et al. (2004) found that confidence and belonging are often linked where "confidence grew along with a newfound sense of professional belonging."
- *S7: Graduate school and career preparation* (24 responses). Aligning with the literature on STEM UREs (Humphreys 1997; Russell, Hancock, and McCullough 2007; Eagan et al. 2013), survey participants mentioned that statistics majors who participate in UREs seem more likely to go to graduate school. Similarly, participants emphasized the career advantage gained from an URE. One survey respondent commented that "several students have told me that their undergraduate research was a significant portion of what they were asked about when applying for jobs, and that they thought it was an important part of why they had gotten the job they had."
- *S8: Statistical research exposure* (26 responses). Survey responses described the importance of exposure to the

process of statistical research and what it means to do research in statistics. Since research is a significant component of one's graduate education, exposure to statistical research can help a student determine if they would like to pursue an advanced degree. Lopatto (2003) summarized a faculty survey of student benefits, which includes as a benefit that students "learn what scientific research actually entails."

Three core student benefits were identified in the literature but missing from our survey responses. These include:

- *S9: Learning to use scientific literature*. Lopatto (2003) discussed how developing the ability to read the scientific literature is both an essential feature and a desired student benefit of UREs.
- *S10: Networking*. Seymour et al. (2004) discussed the importance of learning from faculty mentors how to develop and use a professional network as part of their development. Students should not only attend conferences but the faculty mentors should use the opportunity to introduce the students to other statisticians.
- *S11: Ethics*. Instruction in the ethical conduct of scientific research is given as a benefit in Lopatto (2010). He also notes that there is a positive correlation between a student's perceived gain in learning about ethics and ethics instruction. This student benefit could be gained in a statistics URE by reading and discussing the ASA's Ethical Guidelines for Statistical Practice (ASA 2018a).

2.2. Benefits to Faculty

It is informative that survey participants overwhelmingly described student benefits, rather than faculty benefits, from undergraduate research. Of the 106 free text responses regarding benefits, only three mention faculty benefits. This sentiment that students receive the bulk of the benefits has been noted elsewhere in the URE literature (Lopatto 2010). We can, nevertheless, identify tangible benefits for statistics faculty. A primary benefit should be in advancement toward promotion and tenure. Typical tenure and promotion guidelines reference teaching, scholarship, and service, each to varying degrees depending upon the nature of the institution. Statistics faculty supporting UREs may find improvement in all three of these areas.

We outline below some potential benefits to faculty that we have recognized from our collective experiences, along with references to similar observations in the literature.

- *F1: Teaching growth*. Undergraduate research in statistics involves three aspects of teaching. First, the mentor must frequently review and deepen students' understanding of their coursework. Second, UREs provide an opportunity for the mentor to reinforce the undergraduate students' ability to become an independent learner. Third, material may be entirely new, and perhaps beyond the scope of any offering at the student's institution. Here, there is an opportunity for faculty to teach new material. Such just-in-time teaching not only benefits the student, but may also reinforce a faculty member's understanding of an advanced topic. As Gentile (2000) claimed "research with undergraduate students is in itself the purest form of teaching."
- *F2: Advancement of scholarship*. While the connections to scholarship are perhaps obvious, the challenge can be to distinguish research from student projects. Given the right circumstances, undergraduate majors may be able to provide important support to faculty in their own research agenda (Osborn and Karukstis 2009). This is true even for theoretical or methodological research, although it may involve greater efforts to teach the student necessary material that might not have come from their regular coursework. If a student is not prepared to contribute in this fashion, faculty can find other ways in which a student can help. We broach this issue more in Section 4.2.
- *F3: Strengthening service contributions*. The discipline of statistics provides a unique way by which we can contribute to the community through UREs. Research problems that involve the application of statistical methods routinely originate in other fields, and the opportunity is thus significant for faculty to develop interdisciplinary partnerships via UREs. It should be stressed that these collaborative research projects should be regarded as both institutional service and legitimate scholarly activities (ASA 2018b).

2.3. Institutional Benefits

The benefits of a vibrant undergraduate research program extend beyond those experienced by individual students and faculty, and can be felt by institutions of higher learning. In this section, we briefly describe some such institutional benefits.

- *I1: Recruitment and retention*. Research has shown that many students who enter higher education with an interest in pursuing study in STEM lose that interest before degree completion (National Academies of Sciences, Engineering, and Medicine 2016). Institutions can point to successful student-faculty collaborations as a mechanism for increased retention. Although there is a paucity of work related specifically to statistics, literature from STEM fields indicates a strong relationship between collaborative learning (including UREs) and recruitment and retention of students (Gregerman et al. 1998; Lopatto 2004; Laursen 2019). Participation in research activities has also been shown to act as a pathway into science careers and graduate programs for minority and female students (Hathaway, Nagda, and Gregerman 2002; Lopatto 2004).

  A study at Northern Kentucky University (NKU) found that the odds of being retained in the major were six times higher if a student participated in Project FORCE, a STEM-based program that included undergraduate research as a primary supported intervention (Bowling et al. 2016). More investigation is needed to establish whether statistics UREs show the same relation with retention. Anecdotally, our survey indicated that faculty do believe that undergraduate research participation leads to growth in student excitement and confidence, and a sense of belonging in the field. In particular, faculty commented that undergraduate research "raises interest for further education," "inspires students to

go on in statistics," and represents an "introduction to the fun part of the subject."

- *I2: Development of collaboration centers.* Applied statistics is, by its nature, interdisciplinary. A collaboration center can be an asset at every institution of higher education. A well-staffed center can serve the institution internally, providing assistance to faculty at relatively low expense. Legler et al. (2010) found that their center at St. Olaf "invigorated research all over campus" with many faculty and staff eager to participate. As in St. Olaf's case, the center may even contribute to interval review and improvement by including projects from, say, admissions or institutional research. Such a center may also have externally facing arms, helping to build quality relationships between the institution and community businesses and nonprofits. For example, NKU's Burkardt Consulting Center involves substantial collaborations with regional medical organizations.

3. Barriers

Undergraduate statistics research programs face numerous barriers which may prevent successful integration into a broader statistics program. Such barriers may originate from challenges that faculty perceive, from the students who are intended to conduct the research, or even from the institution housing the program. In our survey, almost all faculty (97%) focused on benefits when discussing student involvement in undergraduate research. Interestingly, when discussing barriers to undergraduate research, faculty respondents were much more likely to mention their own barriers to involvement. Seventy-six percent of responses to the barriers question discussed faculty barriers, 31% mentioned institutional barriers, and 26% mentioned student barriers. Tables A3–A5 contain the themes related to student, faculty, and institutional barriers, respectively, that we found in the survey responses.

3.1. Perceived Student Barriers

3.1.1. Student Interest in Undergraduate Research

The most commonly cited student barrier in the survey responses was a perceived lack of interest in undergraduate research. As one respondent stated "Many students are not motivated to conduct this kind of research, they are not willing to spend the time needed." It should be stressed that this is a perceived barrier and may not be an actual barrier. UREs often require students to make contact with faculty but research has found that science faculty are often considered inaccessible or unapproachable (Vogt 2008), which may dissuade students from seeking out opportunities, and be mistaken by faculty as disinterest.

3.1.2. Financial Support

Lack of financial support is also a key barrier to participation from the student perspective (O'Donnell et al. 2015). (In Table A5, we list the issue of compensation as an institutional barrier although it is clearly a barrier for all three groups.) Even students who are excited about the prospect of doing research will frequently be unaware of avenues for funding their interests. Moreover, the research opportunity might require the student to travel to a new location and student compensation may not include items like housing and meals, making other noneducational opportunities more lucrative and accessible (Bangera and Brownell 2014). This is a particular disincentive for students who view their summer activities as a main source of income to pay for tuition and other expenses. When research is conducted during the academic year, say as an independent study, students may additionally have to pay for associated credit hours.

3.1.3. Availability of Opportunity

Despite more direct disincentives, many survey respondents mentioned an inability for their department to meet the demand for research experiences among students, with only a select few receiving the coveted positions. As one respondent put it "We could do a better job of recruiting a diverse set of students to do research. Students who have done research in the past often approach faculty about doing more research, but it would be good to get more students involved in research projects for the first time."

To that end, undergraduate research programs may also suffer from a lack of engagement from some of the student groups they aim to serve. For example, self-doubt and imposter syndrome can prevent many interested students from applying to summer research programs, instead favoring more traditional jobs and internships (Kuh 2008). This hurdle can severely limit pools of qualified applicants, as can opportunities that are inaccessible to certain groups of students. A primary example of the latter is that international students in the United States often face a very competitive market since many funds are earmarked for American citizens or permanent residents. Finally, underrepresented students may not fully realize the value of conducting research as an undergraduate, or may not even be aware of such opportunities (Bangera and Brownell 2014). The problem of "access" is a difficult hurdle to overcome: how do we reach this set of students, make them aware of what is available, and convince them that they are both capable of doing the work and that it will be a beneficial experience?

3.2. Perceived Faculty Barriers

3.2.1. Time

Perhaps the biggest barrier facing faculty members who are interested in supervising UREs is the availability of time. Sixty-eight percent of the survey participants mentioned "time" when discussing barriers. Taking additional time to train students seems like a tremendous task, and may be viewed as expendable. Related to this is perhaps the single greatest stressor in many college faculty members' early career: procuring a tenure-track position and subsequently attaining tenure. The manner in which an activity counts toward this process can be a primary factor in faculty willingness to make an investment of their time.

3.2.2. Student Background and Preparation

Related to time, training undergraduate students is a time-consuming endeavor where, as one survey respondent put it, "to guarantee success the undergrad needs close monitoring, clear directions, and guidance throughout the process." Thirty-one

percent of survey participants mentioned that their statistics program simply isn't robust enough to fully prepare students for statistics research. Further, faculty at undergraduate-only institutions (e.g., liberal arts colleges or community colleges) do not have graduate students to serve as go-betweens on a day-to-day basis. Moreover, many of the students most qualified for research projects are also close to graduation (and leaving) by the time they are fully ready to contribute. This creates a situation where the training portion of a faculty member's workload may seem perpetual, thus becoming a major deterrent to undertaking mentorship of students. And while the training is very important to the student, it may not be an important contributor to the faculty member's tenure/promotion application.

3.2.3. Tenure and Promotion Hurdles

Junior faculty are challenged with transitioning from graduate school (or post-doctoral) work where their main task is the production of original research. In their first few years in a faculty position they must design and implement several new courses, grade student work, hold office hours, and find ways to participate in their college's administrative duties. They also must work toward establishing their own research agenda, which may involve attending conferences, networking, and searching for funding. It is a daunting time for many young professors, who may also have young families and are trying to strike an appropriate work-life balance.

Some surveyed faculty expressed the conviction that supervising undergraduate research slows productivity and also lessens the potential impact of publications that may be very important in the tenure/promotion application. Consequently, although individual faculty may place great value on mentoring undergraduate students, they may be reluctant to undertake tasks that seem incompatible with the goal of maximizing scholarly output. Incorporating undergraduate research is made even more difficult as, with continual turnover of students, there is a very real possibility that projects are incomplete at the time of a student's graduation. Depending on a student's future plans, the incentive to continue a project after graduation and see it through to publication may not exist. As one survey participant indicated, undergraduate research may not be feasible for some faculty due to "low return on investment."

Availability of faculty for UREs does not necessarily improve when the tenure hurdle is removed. While the pressures of review are diminished, faculty are frequently placed in positions having increased amounts of administrative work. Those commitments may serve to prevent them from having the time needed to incorporate undergraduate students into their research.

3.2.4. Finding Projects, Data Sources, and Funding

Finding appropriate projects and good datasets with enough domain motivation was another commonly cited barrier. Faculty felt they did not have the resources to curate projects and that student interests often did not align well with the faculty's statistical expertise. As one respondent mentioned "many students want to pursue specific projects in areas where the faculty may have relatively little expertise or interest." And since the interests and abilities of students can vary, one respondent expressed difficulty in "coming up with enough good research project ideas to accommodate all undergraduates interested in pursuing research in statistics."

Finally, the matter of finding funding for students who conduct research during the summer will ultimately fall to the faculty supervisor. Students in statistics and data science are increasingly finding paid internships and jobs, with stipends that are difficult to match in an academic milieu. The need to search for competitive financial support for students will further dissuade many faculty members from entering the realm of undergraduate research supervision.

3.3. Perceived Barriers From the Institutional Perspective

The two most commonly mentioned institutional barriers were a lack of adequate compensation and limited staffing in statistics (see Table A5). Issues of compensation seemed to go hand-in-hand with perceptions that the survey respondent's institution did not place much value on undergraduate research. Limited staffing in statistics relates to both faculty and student barriers as limited staffing often means there are minimal course offerings to prepare students for research and few faculty to mentor undergraduate research.

From an institutional perspective, the value of undergraduate student research may be diminished if the desired outcome is research published in the highest impact journals in the field. For example, R1 universities may want their faculty to focus all of their time and energy on literature that will be published in highly selective, leading journals; this may not be compatible with the level of results produced by undergraduate research projects. The following survey response summarizes what seems to be a common sentiment: "My institution 'values' undergrad research but in terms of annual evals and P[romotion] and T[enure] it is not really given any weight. More emphasis is put on publications and grants so spending time with undergrads is often frowned upon."

Another difficulty faced by institutions involves their own internal support and recognition mechanisms for students participating in UREs. It is difficult to set campus-wide standards and expectations when research norms vary greatly by department, and value placed on undergraduate research may vary widely by faculty from different disciplines, both within STEM, and across the social sciences, humanities, and arts. For example, statistical consulting is both accessible to undergraduate students and an avenue to publication. Because this is somewhat unique to the discipline of statistics, a challenge for any campus considering the establishment of such a consulting-style center is how to support supervising faculty for their efforts (Legler et al. 2010). Of course, perhaps most important from an institutional perspective is the monetary hurdle; even if research with undergraduates is valued, it may be prohibitively expensive to adequately compensate students and faculty.

4. Overcoming Barriers

Interest in undergraduate research is growing, especially among students and the institutional offices in charge of student recruitment (Spears and Hardy 2011). However, many survey

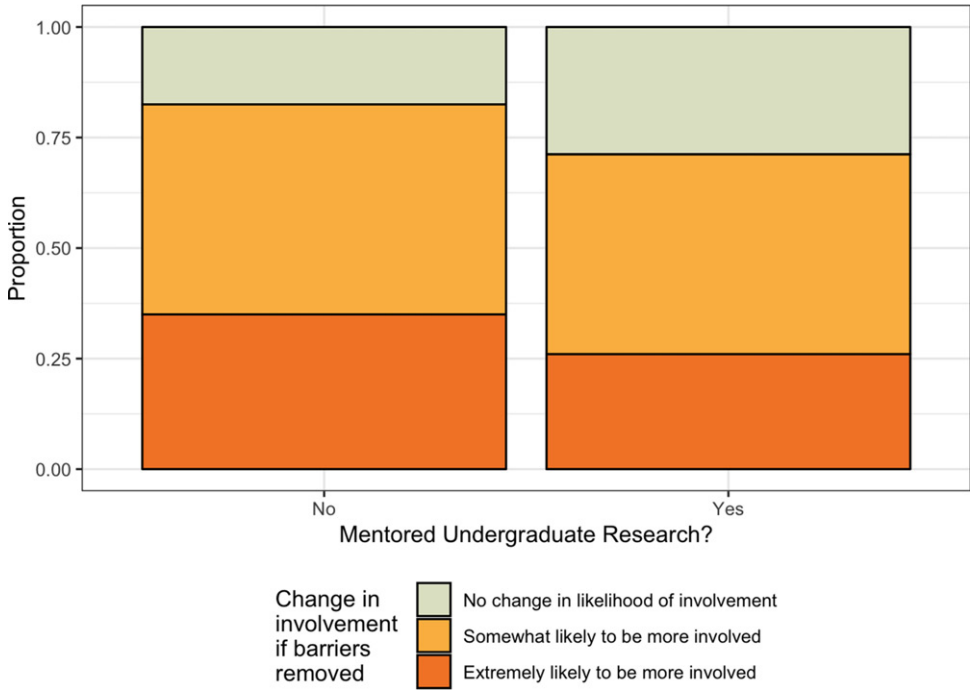

Figure 1. Survey responses to the question "If the barriers you mentioned were removed, how might that change your involvement in Undergraduate Research in Statistics?" broken down by whether or not the respondent had previously mentored undergraduate research.

participants acknowledged that their department can only meet a fraction of the demand because of barriers that limit faculty participation. To fully meet demand will require greater involvement from statistics faculty and more efficient use of faculty time in mentoring. Fortunately, greater involvement in undergraduate research seems possible since a majority of survey respondents said their likelihood of involvement would increase if their perceived barriers were removed (see Figure 1 and Table A6). Of the surveyed faculty who have not mentored undergraduate research, over 80% expressed a higher likelihood of involvement if barriers were removed. Their involvement could substantially help in terms of meeting the student demand.

4.1. Overcoming Perceived Student Barriers

Increased student engagement in undergraduate research is possible when students are informed of the benefits and value of these opportunities, when institutions provide more financially supported research opportunities, and when these experiences are properly advertised.

4.1.1. Fostering Inclusivity

Since the most commonly perceived student barrier in the survey responses related to a lack of interest, it is important that faculty articulate what undergraduate research involves and its merits. This is a crucial message, in particular for those considering careers outside of academia, and mirrors broader findings in science (Tobias 1990; Tobias, Chubin, and Aylesworth 1995). Effective programing related to UREs can help to alleviate many issues surrounding access. In departmental seminars, faculty should showcase and advertise undergraduate research opportunities on- and off-campus. The department should also host informal informational sessions where a diverse group of students discuss their UREs and institutions should host yearly campus-wide undergraduate research poster sessions. These sessions can help other students to see how they too could be successful at research. To ensure all statistics students know about undergraduate research opportunities, faculty can also spend a few minutes of class time to talk about the benefits of participation in UREs.

4.1.2. Addressing Financial Support

Institutions should have clear, campus-wide, or at least department-wide, policies for summer research opportunities that provide students with information about the whole financial package, including the stipend amount, travel funds availability, and the projected costs for room and board. For research conducted during the regular school year, there should be policies for how it can be incorporated into a student's work-study. Faculty should be mindful that research conducted for course credit does not conflict with a student's work-study. For example, at NKU's Burkardt Consulting Center, student consulting positions are treated as internships to allow students to receive course credit in addition to hourly pay. It is important to avoid making students choose between the benefits of undergraduate research and their financial support. Research opportunities available on-campus and links to other opportunities should be posted and widely publicized to students. For example, opportunities for American citizens and permanent residents to work on NSF projects are posted at *www.nsf.gov/crssprgm/reu/reu_search.jsp*.

4.2. Overcoming Perceived Faculty Barriers

Many of the barriers perceived by the surveyed faculty suggest that they do not currently see mentoring undergraduate

research as part of their "day job." Participants felt that mentoring undergraduate research represents an extra task for which they do not have the time nor are they incentivized to do and when they do participate, they do not feel the work is valued. This section describes techniques for integrating undergraduate research in statistics into a faculty member's prescribed set of responsibilities, for getting recognized for this work, and for securing funding.

4.2.1. Finding and Managing Time

Perhaps the ideal solution to the time barrier would be a *perfect* time swap between other departmental and institutional responsibilities and undergraduate research. For example, the faculty member's teaching load might be reduced so that time can be spent mentoring undergraduate research. Unfortunately, this scenario of a zero-sum tradeoff isn't realistic as the precise time needed for each commitment ebbs and flows during any given year. In certain environments, the opportunity may exist for faculty to incorporate undergraduate research into current commitments. For example, they might teach a group research or capstone course where students conduct research projects or involve students in already existing statistical consulting projects. Reed College offers such a course, called "Statistics Practicum," where the students work on semester-long group projects generated by Reed faculty and staff. And while a reduced teaching load may not be possible, one can request scheduling arrangements that would better support their research efforts. This might include reducing the number of preps, arranging for a day or two a week with no teaching duties, or perhaps providing separate dedicated office or lab space where faculty and students can conduct their research. For example, St. Olaf College very purposefully placed their CIR right between the natural sciences and the statistics program to encourage the use of the space, which is open to the CIR researchers day and night (Legler et al. 2010).

Effectively mentoring undergraduate students is a laborious, time-intensive task but there are strategies for reducing the workload. One approach is to have at least two students working together so that they can support each other. Lopatto (2010) found that students really appreciate working with their peers and that 37% cited it as "one of the best parts" of the URE. Per-student mentoring time can be greatly reduced with larger groups and can be manageable in total when faculty team up and focus on the mentoring components in which they have expertise. Also, if possible, faculty should recruit underclass students, as this provides more time to fully train them and a higher chance that the project progresses to a peer-reviewed manuscript while the students are still on-campus. Additionally, those students who are able to start early can then help to peer mentor future research students. Students who have served as peer mentors have reported benefits of increased confidence and a greater appreciation for their research (Lopatto 2010).

4.2.2. Aligning UREs With Faculty Research Goals

It is useful when the undergraduate research moves the faculty's own research agenda forward, resulting in tangible outcomes such as presentations and peer-reviewed articles. However, the feasibility of integrating students into existing projects depends greatly on the area of the faculty member's work and the theoretical sophistication required. Many undergraduate students are not prepared to make methodological contributions, and if that is deemed to be the case, then faculty must determine how students can feasibly participate in a productive and meaningful manner. We see several viable avenues forward in such instances:

1. Running analyses for applied collaborations from client disciplines.
2. Assisting with nontheoretical aspects of projects, for example, simulation studies, data collection, data cleaning.
3. Contributing to open source software packages.
4. Converting code written for one specific dataset to reproducible code.
5. Porting code from one statistical software language to another.

Hydorn (2018) outlined several types of undergraduate research projects in statistics. Moreover, faculty with a research agenda in statistics education can gain a tremendous amount from a student's perspective. Students might also contribute by developing apps to be used in teaching, and helping to conduct surveys, experiments, and/or field-tests. For student-initiated projects, faculty must be strategic in what they agree to mentor, and should be prepared to say "no" when the projects do not align well with their expertise.

To address the preparation of students so they can be more helpful in contributing to faculty research programs, Research Experiences for Undergraduates (REU) centers can run bootcamps or short courses at the start of the summer before the REU begins. Prominent examples include the Research for Undergraduates Summer Institute of Statistics (15 students supported by the NSA and NSF; see *https://stat.oregonstate.edu/rusis%40OSU*) which has been held annually for 16 years, and the Mathematical Biosciences Institute REU (≈8 students supported by NSF; see *https://mbi.osu.edu/education/summer-reu-program*). When students are asked to work in teams, these bootcamp experiences can also help to level the playing field so that every student can make valuable contributions to team efforts. For smaller, individual summer reseach programs a student might take a reading course on the topic during the spring semester to prepare for their summer work.

4.2.3. Creating Tangible Outcomes

Part of building a successful program is ensuring that the work is recognized since this recognition can incentivize future faculty participation and can demonstrate the value of undergraduate research to the institution. Faculty should share any outcomes of the work with the various campus stakeholders, such as department chairs, deans and provosts, and key institutional offices, such as admissions, public affairs, and the development office. Students should present their work both on-campus and off-campus at national conferences, such as the National Conference on Undergraduate Research, the Nebraska Conference for Women in Mathematics, or the Electronic Undergraduate Statistics Research Conference (eUSR). All eUSR presentations are posted to the website shortly after the conference, allowing students to share links to their work with future employers.

The faculty should also encourage the students to compete for national awards, such as the Goldwater Scholars, and to submit their work to national competitions, such as the Undergraduate Statistics Project Competition (USPROC). USPROC posts the winning projects on their website. Participation in such opportunities has already shown growth; for example, the USPROC has seen its number of submissions double in the past 5 years. When possible, the work should be published in a peer-reviewed journal or an undergraduate research journal, such as *Involve: A Journal of Mathematics, SIAM Undergraduate Research Online*, or *The Rose-Hulman Undergraduate Math Journal*. To the best of our knowledge, there does not currently exist an undergraduate research journal devoted exclusively to the field of statistics.

4.2.4. Securing Funding

Faculty are wise to seek funding for their undergraduate student researchers. They should first explore what possibilities may exist internally through the department and the college, as many institutions have funds that are earmarked for UREs. For external sources, the faculty member should work with their institution's office for sponsored programs to learn about national grants that may support UREs in statistics, such as the NSF Research Experience for Undergraduates Sites and Supplements awards (NSF-REU), the NSF Facilitating Research at Primarily Undergraduate Institutions awards (NSF-RUI) and the NIH Research Enhancement Award (NIH-R15). Each year the NSF gives out 1600 supplement awards across all directorates. Recently the ASA received an REU grant and was able to support statistics related REUs at nine institutions (Ward 2018). While REU programs in statistics are continually changing, an updated listing is available on NSF's site (*https://www.nsf.gov/crssprgm/reu/list_result.jsp?unitid=5044*).

A student's federal work-study can also be applied to doing undergraduate research with a faculty member. Dorff and Narayan (2013) suggested reaching out to your financial aid department for help on incorporating federal work-study in an URE. The development office is another resource they recommend as the development staff may know of alumni who would be interested in funding UREs. For instance, Reed College's internal grant for students to conduct summer undergraduate research in the sciences is funded by alumni giving. California Polytechnic State University, San Luis Obispo, recently received an alumni gift, one of the largest in California public higher education, to support undergraduate research (Lazier 2017). This gift supports 20–25 undergraduate research projects in the Statistics Department each year.

Funding can be available from government contracts or local businesses who have compelling data and questions. The Reed Forestry Data Science Research Lab, for example, is funded by the institution and by the USDA Forest Service Forest Inventory and Analysis Program. At Dordt, a local engineering firm decided that, rather than have internships on their campus and mentored by their engineers, who have little experience working with undergraduates, they would fund student interns, and a portion of associated faculty salary, for students to work on Dordt's campus, mentored primarily by Dordt faculty but on a project of interest to the funding firm. This win-win-win model (The firm gets to support interns, receives the outcomes it wants, and sees little impact on their employees time; The students gets real world experience mentored by experts in undergraduate education; The faculty receive funding for work with students and participate in cutting edge projects) is of increasing interest to local businesses. These funding ideas of course require networking by the faculty member and the development office, who must have the ability to pitch the utility of UREs in statistics. We hope the benefits provided in Section 2 embolden statistics faculty to take up this challenge.

4.2.5. Finding Data Sources

There are many potential resources for publicly available data. The Microsoft R Application Network (*https://mran.microsoft.com/*) keeps a curated list of various datasets and Kaggle (*https://www.kaggle.com/*) has a repository of nearly 20,000 datasets. You can also search for data with the Google Dataset Search tool (Noy 2018). The federal government's data site, Data.gov, provides access to a variety of federal data sources, as well as links to open data sites at the city, county, and state level (*https://www.data.gov/open-gov/*).

4.2.6. Compensation

Since faculty time is limited, directly compensating faculty for time devoted to supervising undergraduate research may be an important mechanism for promoting it. One survey question considered the ways that institutions incentivize faculty involvement in undergraduate research (see Figure 2 and Table A7). Strikingly, the greatest difference in undergraduate research mentorship rates was between schools that provide direct additional salary and schools that do not. The remaining three incentives shown in Figure 2 also had at least slightly higher rates among those surveyed when the incentive was available, suggesting that indirect compensation may help but may not be as likely to motivate as many faculty to participate. Valuing involvement in undergraduate research toward tenure and promotion was by far the most common incentive that faculty were aware their institution employed.

4.2.7. Conducting a Successful URE

While not addressing a specific barrier, here we suggest strategies for creating a successful URE. Regardless of how undergraduate research is incorporated into a faculty member's commitments, strong planning and time management skills are required to ensure a successful experience. Before starting a project, faculty should create a structured research plan with clear goals and should set regularly scheduled research meetings as research shows that this structure correlates with higher student satisfaction in the URE (Lopatto 2010). During the project, faculty should assign weekly tasks, and require students to monitor their progress by keeping an activity log. As the project progresses, some of the ownership may be shifted to the students by asking them to take a greater role in determining weekly tasks and giving them more leeway for creativity. Storing the work using a collaborative, version control system such as Git (*https://github.com/*), ensures mistakes can be undone and retains a record of how each person has contributed to a project. At the end of the project, the faculty should provide the students with the opportunity to evaluate the experience so that this feedback can be used for future planning. Both the CURE survey and survey of undergraduate research experiences

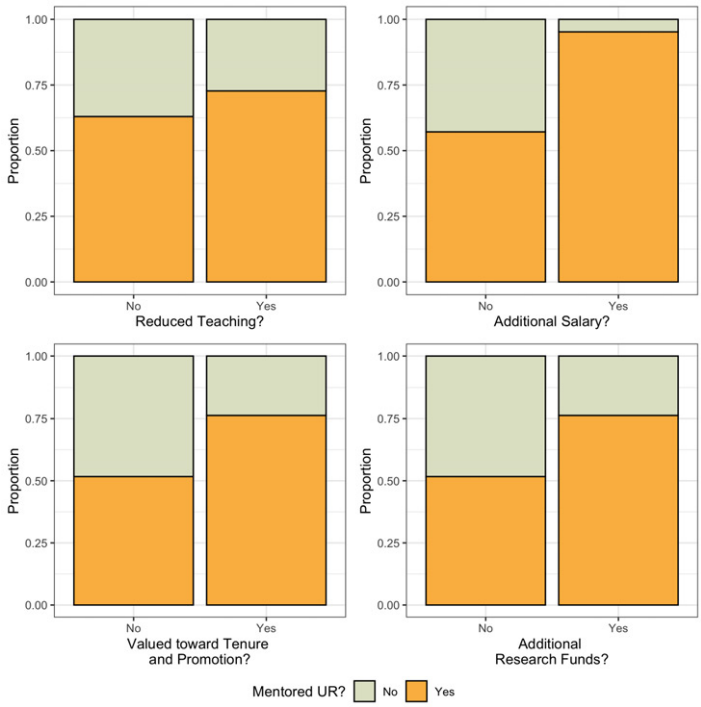

Figure 2. Undergraduate research mentorship rates based on whether or not their institution uses one of these incentives to encourage faculty participation.

provide online assessment materials that faculty can adapt for their own UREs (Grinnell College 2018).

In addition to project-specific considerations, campus-wide programing can help bolster the URE. During their summer URE, California Polytechnic State University, San Luis Obispo hold faculty-run seminars on topics such as GitHub to help development research skills. And, faculty at Reed College organize the Reed Empirical Research Workshop Series as a venue to bring in community speakers and to give students an opportunity to present their work. In surveys of students who participated in undergraduate research, Lopatto (2010) found clear correlations between the reported learning gains and related programing. For example, greater career path clarification correlated with outside scientists presenting their work.

4.3. Overcoming Perceived Institutional Barriers

4.3.1. Highlighting Undergraduate Research On-Campus

Overall, the most significant institutional barrier is finding the necessary resources to appropriately compensate faculty and student time spent on undergraduate research. This might require a shifting of institutional or departmental priorities and even an updating of the job requirements of professors so that undergraduate research is an explicit component of the job and of the Tenure and Promotion process. To facilitate these changes, faculty should highlight how undergraduate research benefits the institution or department, and supports its mission. For example, faculty may need to clearly point out the invaluable service role played by cheaply involving undergraduate students on projects from across campus, and the local community. These arguments could highlight how on-campus undergraduate student researchers with data analysis interests can simultaneously support other on-campus faculty and student researchers or help meet institutional research/admissions goals. These "low-cost" students gain valuable on-the-job experience while simultaneously filling a need that most institutions increasingly recognize—data can enhance efficiencies and finances at academic institutions, but there is a significant shortfall in the number of individuals available who have the expertise to analyze the data. For example, data science and statistics students at Dordt increasingly are given internships in admissions, institutional research, and are embedded in other faculty labs across campus.

Faculty arguments for increased support are most persuasive when the institution values undergraduate research. But for the institution to value undergraduate research, administrators must see the positive outcomes of UREs. Unfortunately, to fully see the impacts of UREs, institutions may need to first properly invest in it. To resolve this "catch-22," faculty may need to donate some of their time in the short-term so as to eventually convince their institutions to develop fair and appropriate ways of valuing undergraduate research in the long run.

4.3.2. Supporting CUREs On-Campus

If unable to provide additional salary, the administration could provide programming and support for faculty to convert some of their courses to the CURE format. From an institutional perspective, CUREs are an attractive option since they may scale the URE to a larger number of students than is often feasible for non-course-based UREs. With funding from an NSF Improving Undergraduate STEM Education award, faculty at Arizona State University have created several CUREs which are open to their statistics majors. At Macalester College, the Senior Capstone requirement has been converted from the completion of an independent project to the completion of at least one CURE. For example, students interested in statistics at Macalester College can take courses like: Bayesian Statistics, Correlated Data, Causal Inference, Survival Analysis, and Projects in Data

Science. Supervision of Senior Capstone projects has thus been incorporated into a faculty member's regular teaching load via the introduction of CUREs. Additional examples of statistical CUREs can also be found in Delzell (2012) and Boomer, Rogness, and Jersky (2007).

5. Conclusion

Given the numerous benefits of UREs to students and the increased desire for research opportunities, now is the time for statistics faculty to engage with their institutions about ways we can better value and support undergraduate research. We encourage faculty to take this article to their department chair and their administration and to start a conversation about how undergraduate research in statistics fits into their institution and how it supports their mission. We hope that conversation will move beyond valuing undergraduate research to exploring ways in which the administration can help with appropriate compensation and mitigation of some of the other barriers discussed herein. Such campus conversations also require us to acknowledge differences in UREs in statistics as compared to other disciplines (e.g., lab sciences). While there are many difficulties in UREs in statistics, there are also features of statistics that make it a compelling venue for undergraduate research. As statistics is inherently interdisciplinary, applied undergraduate statistics research allows students and faculty to engage in another discipline. As the demand for statisticians and data scientists continues to outpace the supply, UREs in statistics can also be a way of strengthening and diversifying the pipeline of future statistics majors by exciting students about careers in the field.

Appendix

The survey questions are given below. Questions 1-7 included checkboxes as described:

1. Institution Type: 4-year Public (with graduate degrees), 4-year Private (with graduate degrees), 4-year Public (without graduate degrees), 4-year Private (without graduate degrees), 2-year, High School, Other (please specify).
2. Does your institution offer any of the following? (Please select all that apply): Undergraduate Major in Statistics, Undergraduate Major in Data Science, Minor or concentration in either Statistics or Data Science, Other related major (please specify), None of these
3. Academic Position: Professor, Associate Professor, Assistant Professor, Other Full Time Position, Other Part Time Position
4. We define Undergraduate Research in Statistics to include undergraduate students conducting research projects that are statistically related (either methodological or applied). Undergraduate research therefore would include things like work from summer/REU research projects, senior capstone projects, or independent research projects. We distinguish Undergraduate Research from class projects, which are included as part of regular course work at the introductory or intermediate level. Please select all that apply: (a) I have mentored Undergraduate Research in Statistics. (b) I have incorporated projects into an undergraduate statistics class at the **introductory** level. (c) I have incorporated projects into an undergraduate statistics class at the **intermediate** level. (d) I have neither mentored Undergraduate Research in Statistics nor incorporated projects into an undergraduate statistics class. SKIP LOGIC: If (a) is not selected, skip to Q8.
5. I have mentored Undergraduate Research in Statistics…. (check all that apply): For juniors and/or seniors, For freshmen and/or sophomores, During one or more summers, During one or more regular semesters, As part of a classroom environment.
6. Which of the following outcomes have resulted from your mentoring Undergraduate Research in Statistics within the last five years? (Please check all that apply): Publication in a peer-reviewed journal, Publication in a journal that focuses on undergraduate research, Oral/poster presentation at your institution, Oral/poster presentation at a Regional/National conference, Honors or Awards, Enhanced postgraduate opportunities (grad school/employment), Other (please specify).
7. Please answer each of the following with a natural number. (a) For how many years have you been involved in mentoring students for Undergraduate Research? (b) How many undergraduate students have you mentored within the last year? (c) How many undergraduate students have you mentored within the last five years?

Questions 8-9 were open ended:

8. What do you see as the most important benefit(s) of Undergraduate Research in Statistics?
9. What do you see as the most important barrier(s) to Undergraduate Research in Statistics at your institution?

Questions 10-12 were check-boxes:

10. If the barriers you mentioned were removed, how might that change your involvement in Undergraduate Research in Statistics? (a) Extremely likely to be more involved, (b) Somewhat likely to be more involved, (c) No change in likelihood of involvement, (d) Somewhat likely to be less involved, (e) Extremely likely to be less involved.
11. What programs/opportunities are available to incentivise Undergraduate Research for students at your school this year? (please check all that apply): Course Credit, Requirement for Major or Minor, Student Award/Honors Program, External Funding from National sources (e.g., NSF REUs), External Funding from Local/Regional sources (e.g., regional employers), Internal Funding, Other (please specify).
12. How does your school incentivise faculty to mentor Undergraduate Research as a part of their workload? (please check all that apply): Additional Salary/Stipend, Additional Research Funds (may include travel), Reduced Teaching Load, Valued toward Tenure/Promotion, Faculty Award/Honor Program, Monetary support comes from an external grant, Other (please specify)

Table A1. Survey sample demographics.

Sample description	Count (%)
Institution type	
Four year (with graduate degrees)	
Public	57 (48)
Private	25 (21)
Four year (without graduate degrees)	
Public	4 (3)
Private	18 (15)
2-Year	12 (10)
Other	2 (2)
Institutional offerings (categories overlap)	
Major in statistics	50 (42)
Major in data science	22 (18)
Minor/concentration in either	74 (62)
Other related majors (e.g., math, actuarial sci.)	14 (12)
None of these	30 (25)
Academic position	
Professor	44 (37)
Associate professor	32 (27)
Assistant professor	21 (18)
Other full-time	16 (13)
Other part-time	6 (5)
Mentored undergraduates (categories overlap)	
Including juniors/seniors	70 (58)
Including freshmen/sophomores	34 (28)
During summers	46 (38)
During regular semesters	54 (45)
As part of classroom environment	35 (29)

Table A2. Perceived benefits to students broken down by faculty characteristics.

Benefit	# of responses (%)	Faculty who have mentored UR (%)	Faculty who have not mentored UR (%)	Faculty at four year institutions (with graduate degrees)	Faculty at four year institutions (without graduate degrees)
S1: Breadth and depth of material	23 (22)	20 (29)	3 (8)	15 (21)	8 (38)
S2: Skill development	12 (11)	8 (12)	4 (11)	10 (14)	2 (10)
S3: Learning by doing statistics	44 (42)	24 (35)	20 (53)	32 (44)	7 (33)
S4: Communication skills	15 (14)	12 (18)	3 (8)	13 (18)	2 (10)
S5: Confidence as a statistician	12 (11)	10 (15)	2 (5)	8 (11)	3 (14)
S6: Sense of professional belonging	29 (27)	18 (27)	11 (29)	18 (25)	6 (29)
S7: Graduate school and career preparation	24 (23)	14 (21)	10 (26)	16 (22)	4 (19)
S8: Statistical research exposure	26 (25)	20 (29)	6 (16)	20 (28)	4 (19)

NOTE: There were 106 free text responses related to student benefits. If a single response spanned multiple themes then it was counted as a response for each theme.

Table A3. Perceived barriers to students broken down by faculty characteristics.

Barrier	# of responses (%)	Faculty who have mentored UR (%)	Faculty who have not mentored UR (%)	Faculty at four year institutions (with graduate degrees)	Faculty at four year institutions (without graduate degrees)
Perceived lack of interest	17 (63)	11 (65)	6 (60)	11 (69)	2 (40)
Access to opportunities	11 (41)	7 (41)	4 (40)	6 (38)	3 (60)

NOTE: Percentages computed from the total number of responses that mentioned a student barrier. If a single response spanned multiple themes then it was counted as a response for each theme.

Table A4. Perceived barriers to faculty broken down by faculty characteristics.

Barrier	# of responses (%)	Faculty who have mentored UR (%)	Faculty who have not mentored UR (%)	Faculty at four year institutions (with graduate degrees)	Faculty at four year institutions (without graduate degrees)
Time	54 (68)	34 (63)	20 (77)	39 (68)	12 (63)
Training and preparedness of students	25 (31)	17 (31)	8 (31)	19 (33)	5 (26)
Not valued toward tenure, promotion or reviews	17 (21)	11 (20)	6 (23)	12 (21)	5 (26)
Finding projects	8 (10)	6 (11)	2 (8)	4 (7)	3 (15)

NOTE: Percentages computed from the total number of responses that mentioned a faculty barrier. If a single response spanned multiple themes then it was counted as a response for each theme.

Table A5. Perceived barriers to institution broken down by faculty characteristics.

Barrier	# of responses (%)	Faculty who have mentored UR (%)	Faculty who have not mentored UR (%)	Faculty at four year institutions (with graduate degrees)	Faculty at four year institutions (without graduate degrees)
Compensation	23 (70)	15 (71)	8 (67)	20 (71)	2 (50)
Staffing in statistics	10 (30)	6 (29)	4 (33)	8 (29)	2 (50)

NOTE: Percentages computed from the total number of responses that mentioned an institutional barrier. If a single response spanned multiple themes then it was counted as a response for each theme.

Table A6. Survey responses to the question "If the barriers you mentioned were removed, how might that change your involvement in Undergraduate Research in Statistics?" broken down by whether or not the respondent had previously mentored undergraduate research.

		Change in involvement if barriers are removed		
		No change in likelihood of involvement (%)	Somewhat likely to be more involved (%)	Extremely likely to be more involved (%)
Mentored undergraduate research?	No	7 (18)	19 (48)	14 (35)
	Yes	21 (29)	33 (45)	19 (26)

Table A7. Undergraduate research mentorship rates based on whether the faculty perceive their institution uses one of these incentives to encourage faculty participation.

		# of responses who mentored undergraduate research (%)	
		Is an institutional incentive	Is not an institutional incentive
Incentives	Reduced teaching load?	8 (73)	68 (63)
	Additional salary?	20 (95)	56 (57)
	Valued toward tenure and promotion?	45 (76)	31 (52)
	Additional research funds?	9 (82)	67 (62)

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