Spring 2015

Access to and Awareness of Undergraduate Research Opportunities at a Large Research University

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Access to and Awareness of Undergraduate Research Opportunities at a Large Research University

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Thesis defended March 30, 2015

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Abstract
The American Physical Society released a statement in 2014 calling on all university physics departments to provide all undergraduate students with access to research experiences. In response, we investigated the current status of access to undergraduate research at CU-Boulder, a large research institution where the number of undergraduate physics majors outnumber faculty by more than five to one. We created and administered two surveys within CU-Boulder’s Physics Department: one probed undergraduate students’ familiarity with and participation in research; the other probed faculty members’ experiences mentoring undergraduate researchers. This report presents results from these surveys as well as a discussion of undergraduate research within CU-Boulder’s Physics Department.
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Acknowledgements

I would like to thank my mentor, Dr. Heather Lewandowski, for giving me this opportunity and mentoring me in my personal and professional development. My gratitude also goes to Dr. Dimitri Dounas-Frazer who has been invaluable in answering all of my questions about “traditions” in the scientific community and in PER specifically. Fellow researchers Bethany Wilcox and Joel Corbo have my thanks for answering my questions about statistics and providing comparison data. I thank my friends and family who have supported me through the last four years of schooling and encourage me to reach for the stars. Finally, I would like to thank my defense committee for their time and support as I conclude my undergraduate career.
Introduction

With the increasing amount of physics education research (PER) being done in the past decade, researchers have started truly studying how undergraduates learn physics. Hardly any of the research in PER concerns undergraduate research (UR) and undergraduate research experiences (UREs) or opportunities (UROs). In a report in 2001, the Boyer Commission stated that undergraduate research was fairly well-established as a staple of undergraduate education, at least for high-performing students. Subsequently, the Association of American Colleges & Universities claimed that UR is a high-impact educational practice that benefits a variety of college students by increasing retention and student engagement. As a research-intensive university, the University of Colorado Boulder houses some of the finest students, professors, and researchers in the world and provides UREs to many students.

With the recently-adopted American Physical Society (APS) statement on UR, CU-Boulder must understand how it can expand student and faculty access to UR in its Physics Department. While UR is conducted in many disciplines and throughout campus and private labs in Boulder, this report focuses solely on the Physics Department. The APS statement speaks directly to this department and it is an appropriately narrow focus for targeted improvements to make some useful contribution to future generations of students and faculty members.

Despite the number of UR projects in the department, there has never been a concentrated effort to understand how students and faculty in the Department of Physics at CU-Boulder conduct UR. The current system involves students approaching faculty to ask for positions in an informal meeting or email; this scattered system may be difficult to augment with departmental procedures. Regardless, understanding the system will reveal if there are possible avenues of improvement that the department and/or institution could undertake. Introducing the concept of research in first-year classes, for example, may be a plausible way to increase the number of undergraduate researchers in the department.

American Physical Society Statement

In April of 2014, the APS Council adopted the following statement:
The American Physical Society calls upon the nation’s four-year colleges and universities and their physics and astronomy departments to provide or facilitate access to research experiences for all undergraduate physics and astronomy majors.

In their brief mention of the context of this statement, the organization emphasized the known benefits of undergraduate research, such as lab skills and knowledge of the field, for the student and how student participation in research benefits STEM fields by increasing retention. A similar statement was adopted by the American Association of Physics Teachers (AAPT) in 2009 and was referenced in the APS statement’s justification.

Definition of “Departments” and Actors

First, we must understand what is meant by the “departments” – specifically, this term speaks to those people within a department and institution who can act on the statement. For CU-Boulder and its Physics Department, this means the students, faculty members, and staff involved with research activities. Staff members would include people such as Kristen Apodaca, the undergraduate coordinator in the department, and Martin Black, the undergraduate physics and astronomy advisor. Institution-wide programs such as the Undergraduate Research Opportunities Program (UROP) are also included in this definition, but staff members from these groups were not questioned since this report focuses solely on students and faculty members in the physics department.

The student population of the University of Colorado Boulder is approximately thirty thousand undergraduate and graduate students. With a variety of colleges and schools, CU-Boulder offers degrees in everything from physics to journalism, environmental design to studio art and theater. Specifically, the quality of science education at this institution is high – the graduate program in atomic, molecular, and optical physics is the best in the nation by *U.S. News & World Report*. The campus has over one hundred research centers and students work in them all. CU-Boulder is a dynamic institution that trains scientists while simultaneously conducting ground-breaking research.
Throughout this paper, many short-hand terms are used for the sake of brevity. When referring to the faculty members who oversee undergraduate researchers, we used the word *mentor* as it embodies many of their responsibilities. Mentors include physics faculty like my own, Dr. Heather Lewandowski; often, graduate students in the faculty member’s research group also help mentor the undergraduate researchers. For logistical reasons, however, we did not question these mentors and confined our attention to faculty members as mentors. Faculty members are also usually a more stable mentoring population than graduate students or postdoctoral students (postdocs). Undergraduates with research experience, whether past or present, were referred to as undergraduate researchers (URers); students without, as non-URers. At CU-Boulder, both physics majors (PHYS) and engineering physics majors (EPEN) are registered with the department; thus they will be referred to by four-letter code where appropriate. These terms will be repeated throughout this paper.

Definition of “Research Experiences” for Undergraduates

The second step to understanding this statement is to understand what is undergraduate research. Defining a term like “undergraduate research” can be done by assessing the goals of the research. The Council on Undergraduate Research (CUR) defines UR as “an inquiry or investigation conducted by an undergraduate student that creates an original intellectual or creative contribution to the discipline.” This definition excludes training for research or small projects that support a larger endeavor. Original research requires extensive funding which most universities cannot provide for every URer and thus we had to find a new definition that does not require truly original research.

Some groups, such as the American Chemical Society (ACS), define UR more broadly by listing prerequisites for authentic UR. In defining UR for our own purposes, we drew mostly from the ACS definition due to its variety of statements and the clarity of those. The following list of traits originates from their report:

- “has a clearly communicated purpose and potential outcomes
• has well-defined objectives and methods...
• has a reasonable chance of completion in the available time
• requires contact with the [field’s] literature
• avoids repetitive work
• requires use of advanced concepts”

For our purposes, we defined UR as broadly as we thought possible to include any experience in STEM outside of the classroom that involved a faculty mentor. We also developed some of our own guidelines in response to the literature on UR. For example, UR should impart on the students a feeling of ownership over the project, as proposed by Hanauer et al. Based on the literature and common practice at CU-Boulder, we further stipulated that UR should include mentor guidance for the student, culminate in a written or oral report or presentation, and provide opportunities for informal communication with the research community. Such a broad definition allowed us to gather as much data as possible from undergraduates who had and had not conducted UR without prejudice against certain types of research projects that the CUR definition would have disregarded.

Definition of “Access”

Now knowing what UR entails, the statement itself seems fairly straightforward until one comes to the word “access.” What is access? Access can be defined as “the ability, right, or permission to approach, enter, speak with, or use; the state or quality of being approachable; a way or means of approach.” In reference to UR, all three of these definitions have different meanings. We focused primarily on three aspects of access: awareness, motivation, and selection.

The ability to do UR is multi-faceted. Not only do the students need to have the theoretical background but they also need self-efficacy in order to approach faculty about research positions. The permission part may be more difficult to ascertain; who needs to give permission for a student to engage in UR? This can change between departments and institutions. One of the most interesting ideas raised by these definitions refers to approachability. For students who

* We removed some traits that, based on interviews with faculty members, were irrelevant to our particular situation.
are shy, lack an understanding of the system, feel intimidated by research, lack the financial resources to take a low-paying job in a high-rent university town, or feel unprepared, UR may be unapproachable.

The statement also raises questions about what it means for a research experience to be significant. For the moment, however, we concentrate on the access part of the statement and assume that undergraduate research activities as reported in our surveys and results fulfill all, or at least most, of the criteria we set forth.

Response to APS Statement

In response to the APS statement, we devised several questions to improve our understanding of how UR works in CU-Boulder’s Physics Department. These questions were:

1. What research-related programs, labs, and groups are students and faculty members familiar with?
2. Why do faculty mentors choose to offer or not offer undergraduate research opportunities to students?
3. Why do students choose to do or not do undergraduate research?
4. How do faculty mentors choose which students to offer undergraduate research opportunities?
5. How do students choose which undergraduate research opportunities to apply for?

The first question (speaking to awareness) probes one of the first steps of access to UR: how students and faculty members learn about available UROs. The second and third questions speak to students’ and faculty members’ motivation to participate in UR. The fourth and fifth questions probe selection by asking how students and faculty actually manage to participate in UR and how they choose what to do or who to work with.

In order to begin improving access to UREs, we must first understand the current state of the field’s understanding of UR; to do this, I present a literature review of PER studies in UR. First I examine past models and themes of UR, which speaks both to access — in terms of students’ and faculty members’ knowledge of UR — and to the actors who may take a part in improving the state of UR within the department. Then I present the known benefits and costs of conducting UR as well as how and why students become involved. Finally, I discuss the gaps in the current research to provide context for our research.
Once a common ground has been established through the literature review, I will discuss the methods used to develop two surveys to answer our five research questions. I will also explain how the measures in these surveys were statistically analyzed after the data collection phase of the project. With the methods understood, I present our data and results. These will follow the outline of the five research questions and will provide some insight into the current status of UR within the Physics Department of CU-Boulder. This section includes discussion of the results. Finally, I present the lessons learned through this project and recommended changes to the surveys.

Literature Review

While too restrictive for our research, the reviewed definitions provided valuable insight into our own work in defining UR. Our definition could include utilizing any of the models of UR reviewed below as well, a choice for each individual department based on its student and faculty populations. Student and faculty perceptions of UR vary; the ways in which students and faculty perceive research can affect a program’s efficiency and public image. Benefits range from personal skills to professional development for students and faculty both. Understanding these aspects of UR can help faculty and students more confidently engage in research together.

Characterization of Undergraduate Research Models

Many institutions and research groups suffer difficulties in determining how to model the UR experience. For students and faculty members, logistical issues such as lab space and instruments may be a factor to consider. The department staff may be more worried about paying student researchers, about liability claims in case of injury, and how the research will benefit the institution’s image in the public sphere. Professors must balance their responsibilities as a teacher with those as a mentor and researcher. Thus, physics education researchers have identified several types of UR from graduate student groups to classroom involvement.

Graduate Students as Mentors

Two groups, Desai et al.\textsuperscript{10} and Dolan and Johnson,\textsuperscript{11} identified a model wherein a graduate student mentored groups of undergraduates. Each faculty member mentored several graduate
students. Desai et al.\textsuperscript{10} pointed out that such a model, which the authors called a research-intensive community, balanced the quality of mentoring for students with the quantity of mentored students. They discussed possible infrastructure for a program to support the community, e.g., undergraduate workshops, but failed to suggest an ideal ratio of undergraduates to graduates.

Dolan and Johnson\textsuperscript{11} showed that these groups enhanced the research experience more than pairs of faculty and undergraduates. They found that undergraduates saw graduate students as more approachable mentors than faculty and also noted graduates exhibited impractical expectations and variable abilities to mentor. The authors used a qualitative approach to analyze the operations of such groups by interviewing the participants. They suggested a framework for building research communities that bring together undergraduates, graduates, and faculty members.

At the Department of Physics at CU-Boulder, graduate students and postdocs often serve as “day-to-day” mentors for many undergraduate students. Students may also report directly to a faculty mentor, but since there are over two hundred graduate students compared to just over fifty faculty members, often it is the graduate students who provide the bulk of a student’s mentoring in professional and personal development.

**Student Roles in Undergraduate Research**

Doulgass and Zhao\textsuperscript{12} described students’ roles in research. Doulgass and Zhao claimed that undergraduates tend to bear two roles in research: assisting faculty in their research and conducting their own independent research. These two roles can often combine, however; students may run a side-project for a larger experiment, for example. This type of research experience, where the student performs a meaningful side-project for a larger research mission, occurs commonly at CU-Boulder.\textsuperscript{13}

**Models of Undergraduate Research Groups**

Zimbardi and Myatt\textsuperscript{14} illustrated four models of undergraduate research. Healey and Jenkins\textsuperscript{15} expressed how research could occur in the classroom. Blackmore and Cousin\textsuperscript{16} organized different styles of UR by the theme behind the research experience.
Zimbardi and Myatt\textsuperscript{14} specified a set of four models. Apprenticeships involved a student-master relationship between undergraduate student and mentor to complete a research project. Industry projects used experts in the industry to guide the undergraduate researcher in his or her work. Students pursued a topic of interest in inquiry projects, a model that requires strength of will and perseverance on the student’s part. Finally, methods courses, in which professors show students how to conduct research, may prove accessible for many institutions when considering how to increase involvement in UR for all of their students.\textsuperscript{14} Within the CU-Boulder Physics Department, most UR projects occur in an apprenticeship model, where the master may be a graduate student and/or a faculty member. Many classes make use of industry projects, especially in engineering classes or capstone courses.

Meanwhile, Healey and Jenkins\textsuperscript{15} claimed that classroom professors can engage students in research in four ways. Research-led courses encouraged students to learn about recent research in their discipline. Research-oriented courses helped students learn research skills. Research-based courses fit more the typical definition, wherein students actually conducted research. Research-tutored courses, similar to research-led courses, involved students discussing research in the context of the course.\textsuperscript{15} Typical lab courses in the physics department follow a research-oriented schema as student learn research skills by exploring well-defined problems that have known solutions. They do conduct some research but it is not nearly as demanding as typical UR projects or faculty research.

Themes of Undergraduate Research

Blackmore and Cousin\textsuperscript{16} found that UR encompasses four major themes. The first is learning within a community of practice, where students observe and work within the research community. Second, students can learn through knowledge production, where students discover the tie between established fact and research. Third, students can practice skills acquisition by managing projects to learn research skills. Finally, conducting research can enhance student achievement.\textsuperscript{16} These themes resemble the models and methods of engagement from above but can inform how to teach a research-based class well as how to conduct UR based on the underlying goal of the project.
Using these ideas of categorization and prioritization of themes and elements of the research process, a research university can build the infrastructure for an UR program that fits their requirements and research culture. To augment such a program, one can also address themes common to UR. Together, such models and themes can help universities trying to define UR for a program or curriculum standard. These models are also useful for the Physics Department to determine what kind of research projects it will support and how it should integrate research with the classroom.

Perceptions of Undergraduate Research

One way to influence engagement with UR is to understand, and then, if needed, change, how students and faculty members perceive it. When these perceptions are positive, UR invites students to engage with faculty research and faculty members to mentor students and help them develop the skills and abilities of a professional. If negative, however, these perceptions can keep students from even attempting to conduct research or approach a faculty member; it can keep faculty members from connecting with students and expanding their research groups to include young physicists-in-training.

Student Awareness of Research

Some research addressed student awareness of faculty research, which is somewhat similar to awareness of UR, particularly when UR projects are done in support of faculty research. Turner, Wuetherick, and Healey\textsuperscript{17} found that students at research-intensive institutions reported higher awareness of faculty research activity than students of non-research-intensive institutions. Students in the study also reported more of both positive and negative impacts of that research on their education than their peers in colleges without as much research.\textsuperscript{17} Spronken-Smith et. al\textsuperscript{18} found that undergraduates tend to report the most awareness of research seminars, followed by staff publications, research consultancy, postgraduate opportunities, and finally research posters and displays. Predictably, upper-division students described more awareness of research than younger undergraduates. Overall, students reported mostly positive awareness of and experiences with the research culture at their institutions.\textsuperscript{18}
programs at universities could impact students’ experiences with their own research by building on this awareness and improving it for younger students.

Student Perceptions of Undergraduate Research

We can examine how students and faculty perceive UR in order to understand how a program at a university may influence these perceptions. Researchers in the UK found that students perceive research in four distinct ways.\textsuperscript{19} New Zealand researchers discovered that physics students felt less connected to research than students in other disciplines.\textsuperscript{20} According to a study in the UK, there exists a relationship between students’ motivation and their perception of faculty research.\textsuperscript{21} While these studies were not conducted in the US, they provided valuable insight into several survey questions of our own.

Levy and Petrulis\textsuperscript{19} interviewed 29 first-year undergraduates participating in research in the arts, humanities, and social sciences at a UK research university. They claimed that students recognized research in four ways: as collecting information (e.g., from experimental data), as performing literature-based research, as conducting independent inquiry, and as discovering and generating knowledge.\textsuperscript{19} By understanding how students perceive research, universities can offer alternative perspectives and meet or surpass the students’ expectations.

Based on interviews with 34 undergraduates studying physics, geography, and English in a large New Zealand university, Robertson and Blackler\textsuperscript{20} found that student perceptions of UR depended on their discipline. They showed that physics students tended to think of research as exclusively the domain of professors and as distant from their education. Students in the other disciplines possessed different views of research; most importantly, they generally acknowledged it as more accessible to them than the physics students did.\textsuperscript{20} Of course, New Zealand and America have different education systems and cultures, so this conclusion may not hold in American universities. Based on personal experience, however, this can be true for many students, especially those from smaller schools or without a local support system (e.g., international students).

Using a Likert-type survey with 71 questions answered by 100 senior undergraduates studying at Oxford Brookes University in Oxford, UK, Breen and Lindsay\textsuperscript{21} found a relationship
between the type of inspiration and students’ perception of the relationship between teaching and faculty research. They found that students motivated by intrinsic values or competency in their courses tended to see faculty research as a positive factor in the faculty members’ teaching abilities. Students with extrinsic, social-oriented, or achievement-oriented motivations perceived that faculty research either inhibited or had no effect on the professors’ teaching capabilities. While not necessarily true for American students, this study does show that “students” are not a homogeneous group; they have a variety of concerns that must be addressed by a UR program if they are to engage with research.

Based on these studies, one can see that undergraduates perceive research in various ways depending on discipline and motivation type. While no research of this type exists in America yet, UR program directors may find it useful to recognize that a variety of viewpoints exist and may depend on major and/or motivation.

Faculty Perceptions of Undergraduate Research

Faculty members perceive UR with as much rich variance as students. Jones and Davis assessed data from focus groups at two institutions to compare how faculty at these institutions perceived UR. They found that faculty opinions of UR changed depending on the amount of time they devoted to their mentoring, the value the institution placed on mentoring, the availability of funding, their students’ dispositions (e.g., student’s work ethic), and the support they received from their institution. They found that faculty mentors supported UR but wished mentoring counted as part of their salaried job. Meanwhile, Dolan and Johnson found that faculty and graduate students, both common mentors of URers, agreed that students contributed to the success of the research group but could also frustrate their mentors due to their inexperience and the amount of time required to mentor them effectively.

Thus, faculty can hold both positive and negative perceptions of UR, as can students. Acknowledging these perceptions can help programs determine how best to approach their advertising and generate student and faculty buy-in. In the Physics Department, based on both formal survey responses and informal discussions, faculty see their position as a mentor to undergraduate students, whether conducting research or not, as an “additional” burden,
something they are not strictly required to do but that is expected of them by both students and their fellow faculty members.

Costs and Benefits of Undergraduate Research

With definition and perceptions of UR in mind, one can examine the benefits and costs of UR. As show below, some benefits seem implicit (such as learning research skills) while others may surprise. Some may coexist in UR and other programs or student activities.

Student and Faculty Benefits

Based on surveys, focus groups, and interviews, studies have produced many benefits and costs for students undertaking UR. Myatt\textsuperscript{23} gathered student gains into three categories: thinking and working like a scientist (e.g., understanding how researchers work), research work (e.g., comfort in discussing scientific concepts with a supervisor or mentor), and becoming a scientist (e.g., the ability to work independently).\textsuperscript{23} Table I uses this approach of categorizing student and faculty gains, though with different categories than from Myatt’s work, in order to present a brief but comprehensive overview of the studied benefits that accompany UR.

As shown in Table I, students derive many benefits from UR. Campbell and Campbell,\textsuperscript{24} in a study of a faculty and student mentor program at a large metropolitan institution on the West Coast, discovered that students who worked with mentors reported higher GPAs than students without mentors. While not explicitly tied to research, Campbell and Campbell’s conclusions demonstrate that mentoring produces benefits of its own unique from those of UR.\textsuperscript{24} From this, we can argue that mentoring constitutes an important part of the research experience for a student, hence why we included it in our definition of UR.

\textbf{Table I.} Student and faculty benefits from participating in UR, as reported by each group unless otherwise indicated:
*Reported by faculty for students
**Reported by students for faculty

<table>
<thead>
<tr>
<th>Category</th>
<th>Benefits for Students</th>
<th>Benefits for Faculty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science-Related Skills and Abilities</td>
<td>Use research skills\textsuperscript{12,15} Use lab techniques\textsuperscript{25} Interpret and analyze results and data\textsuperscript{25}</td>
<td>Improve research skills\textsuperscript{27}</td>
</tr>
<tr>
<td>ACCESS TO UNDERGRADUATE RESEARCH</td>
<td></td>
<td></td>
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<tr>
<td>-----------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Personal Skills</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use proper methodology(^{26*})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use scientific literature(^{26*})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Build awareness of research(^{15})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manage time effectively(^{12})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop qualitative skills(^{12})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tolerate obstacles(^{25,26})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work independently(^{25,26})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Think critically and solve problems(^{28})</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Educational Benefits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learn field knowledge(^{12})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve faculty credibility(^{15})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understand the research process(^{23,26})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understand how scientists work(^{25,26})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understand “fact”(^{25})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve knowledge of a topic(^{26*})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve knowledge of topic(^{28})</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Confidence and Efficacy</strong></td>
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<td></td>
</tr>
<tr>
<td>Discuss science confidently(^{23})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mature intellectually(^{27})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain experience for employment(^{26,29})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepare for graduate school(^{25})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Go to graduate school(^{28})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase confidence(^{27})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mature intellectually(^{27})</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Communication and Networking Skills</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve presentation skills (written and oral)(^{12})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve communication skills(^{12,23})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain professional socialization/networking skills (^{26,30})</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Intrinsic Gains</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain satisfaction with educational experience(^{12})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gain interest in science(^{31*})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase satisfaction in student’s work(^{32})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase faculty enthusiasm(^{32**})</td>
<td></td>
<td></td>
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</tbody>
</table>

Other benefits for student populations include increased under-represented minority (URM) access to STEM,\(^{25}\) higher GPAs,\(^{24}\) increased number of courses completed per semester by the URe,\(^{24}\) and decreased drop-out rates.\(^{24}\) Faculty members also seem to benefit from increased research productivity.\(^{32,33}\) These benefits arise from a variety of programs, so any university seeking to build or improve on a UR program would need to assess the benefits they wish to emphasize for their students.

**Variations in Benefits**

Besides uncovering these benefits, many authors also analyzed what can affect them. Russel et. al\(^{34}\) found that the length of a URE affects benefits but that the timing – summer or semester – produced no measurable effect.\(^{34}\) Thiry et al.\(^{35}\) found that students tend to benefit
more from longer research experiences as well.\textsuperscript{35} These students show that university UR programs should aim to engage students for extended periods. Typically, research projects last at least ten weeks of full-time work (i.e., full-time summer job) and/or a semester or more of part-time research, according to a faculty advisor at CU-Boulder. They can be longer, though very few projects are shorter as less than ten weeks does not allow students to truly immerse themselves in their research.\textsuperscript{13}

In testing the effect of gender and ethnicity, Thiry and Laursen\textsuperscript{30} found that women and minorities gained more confidence from mentor interaction than their male and majority counterparts.\textsuperscript{30} Astin and Astin\textsuperscript{13} found that students running research projects and helping faculty teach express more interest in science.\textsuperscript{13} Since researchers have found that UR brings minority students into STEM fields\textsuperscript{25} and increases interest in the sciences,\textsuperscript{36} university programs could emphasize building confidence through mentor interaction for these underrepresented populations.

Another study by Taraban and Logue\textsuperscript{37} found that high-GPA students benefitted from UREs but students with average GPAs saw no change in their research mindset (i.e., in how they perceived research). They also found that students with low GPAs actually perceived negative consequences due to their involvement.\textsuperscript{37} The program may, then, screen for GPA in order to conserve finances as well as provide the best benefits to students. The authors also discovered that low or average involvement with UR decreases a student’s enthusiasm for and confidence in conducting research.\textsuperscript{37} Thus, on the faculty survey, we asked them how important a student’s GPA and completed classes were when considering them for UR.

Despite knowing the benefits that faculty members gain from mentoring URers, few researchers have studied what affects faculty benefits. Zydney\textsuperscript{38} found that faculty who mentored for an extended period of time and modified their research group(s) to accommodate URers reported more of the benefits from Table I than those who did not.\textsuperscript{38} Desai\textsuperscript{10} also noted that the costs of mentoring and the student-to-faculty ratio at most research-intensive universities rendered one-to-one mentoring unfeasible.\textsuperscript{10} Despite the fewer number of studied benefits for faculty, UR can still be a valuable experience for faculty members. We asked faculty
members why they mentoring URers in order to confirm some of these benefits as well as suggesting others.

Faculty Costs of Mentoring

While benefits for faculty members managing URers number fewer than student benefits, researchers have documented the costs and consequences of mentoring undergraduates. Healey et al.\textsuperscript{29} noted that students complained of the lack of faculty availability and their professors’ tendency to devote more time and resources to research than to teaching.\textsuperscript{29} University programs for UR could emphasize the teaching aspect of the student-mentor relationship to encourage growth in teaching as well as research capabilities on the part of the faculty.

Laursen et al.\textsuperscript{32} noted that inherent challenges, such as lowered productivity and lack of experience, as well as situational strains, like the unresolved issues of how institutions value UR, can render UR a daunting prospect for faculty members.\textsuperscript{32} A successful intervention program would likely need to consider these barriers.

Adedokun\textsuperscript{33} found that faculty members tended to fear failing to motivate their students. The study also found that faculty could struggle with timing and scheduling constraints due to their own and students’ classes.\textsuperscript{33} Support from coordinators in UR programs might help mitigate these struggles to increase faculty participation in UR.

Student Reasons for Conducting Undergraduate Research

One of the most important pieces of research for our purposes looked at why students get involved with research. This differs from the benefits of UR because benefits occur during the experience while students have these ideas before engaging with UR or at least early in the process. Such reasons can motivate students to conduct research; in the informal system here, students need to have at least one reason to seek out a mentor. Thiry and Laursen\textsuperscript{35} found that students in UROP cited their top three reasons to conduct UR as: interest in a topic, to discover what research entails, and to clarify graduate schools or career plans. Their counterparts in BURST (Bioscience Undergraduate Research Skills and Training, a bioscience-targeted companion program to UROP), named their top three reasons as bettering their CV for graduate or medical school, to discover what research entails, and to gain experience for employment or further
studies. The number of students interviewed and the source of interviewees both limit the scope of their research. Despite these limitations, Thiry and Laursen’s research can inform other programs as to the motivations of their participants and improve the match between student expectations and what they truly learn or accomplish.

Conclusion

Despite the attention given to the practice of UR in recent years, there are still gaps in the research. Models and frameworks of UR vary widely between institutions and even the departments within them. Students and faculty members have a variety of viewpoints concerning UR, both positive and negative. While students benefit from conducting UR in many ways, faculty benefits are fewer in number and their costs more obvious. Similar to benefits but distinctly separate, students’ reasons for conducting UR also range, though little research has been done to explore this phenomenon.

Unfortunately, most researchers seem to take for granted the fact that students and faculty members should want to conduct research. As a result, we may not understand why and how students and faculty members actually engage in UR projects. We also lack an understanding of common failure modes in UR. For example, while longer experiences can enhance benefits, can they also put extra stress on a student or the mentor?

We can begin to answer these lingering questions by surveying students and faculty members about their reasons for participating in UR as well as by examining what they would have changed about past UREs. We hope to achieve a basic understanding of these issues through this research project, albeit in the limited scope of CU-Boulder’s Physics Department. An understanding of these gaps at our university will help us respond to the APS statement and facilitate students’ access to UREs.

Methods

Using the literature and previous studies as guidance, we developed five research questions to answer:
1. What research-related programs, labs, and groups are students and faculty members aware of?
2. Why do faculty mentors choose to offer or not offer undergraduate research opportunities to students?
3. Why do students choose to do or not do undergraduate research?
4. How do faculty mentors choose which students to offer undergraduate research opportunities?
5. How do students choose which undergraduate research opportunities to apply for?

We developed two surveys to answer these questions; one collected information from the students while the other asked questions of faculty members in the Department of Physics at CU-Boulder. These surveys are available in Appendices A (student survey) and B (faculty survey) for reference. Here, I describe the methods used to develop the survey questions and the statistical analyses we used on specific questions.

Participants

The Department of Physics at CU-Boulder is known throughout the world for its standards of teaching and research. There are about five hundred undergraduates registered in engineering physics (EPEN) and physics (PHYS) as of spring 2015, a large group that has grown over the years. While EPEN majors are technically associated with the College of Engineering and Applied Science and have a separate course schedule advisor and mentors from the basic physics students, EPEN and PHYS majors take most of the same core physics classes. EPEN majors take applied math courses while PHYS majors can choose either applied or pure math courses. The two majors also have different electives though some courses apply to both. PHYS majors can follow one of three tracks (called Plans 1 (pure physics), 2 (interdisciplinary physics), or 3 (educators)) while EPEN majors only follow one track (sometimes referred to as “Plan 4”).

Data Collection

In designing the student survey, we utilized literature and interview results to inform the wording of questions and options. First, using the sources cited in the literature review, we wrote an interview script and, through the undergraduate coordinator, sent out an email asking for

* More information about these majors can be found on the department’s Program Requirements page: http://phys.colorado.edu/undergraduate-students/program-requirements
volunteers to meet for a 10-30 minute interview. We conducted four initial interviews with two non-URers and two URers. To obtain their informed consent, I presented them with the IRB-approved interview consent form detailing the minimal risks of their participation and the incentive being offered (a $10 gift card). Those interviews were coded for responses that matched the literature and for information specific to CU-Boulder (e.g., particular labs/groups or mentors).

The coding used for these surveys was developed after reading the literature and included institution-specific words such as professors’ names. After those initial interviews, we began designing the survey. We used Qualtrics, an online survey platform to which CU-Boulder owns an institutional license. This enabled us to ask a variety of questions, code the answers in multiple ways, and download applicable data easily and continuously.

In one interview, a student related the difficulty of finding UR on the campus due to the informal application process. From this, we decided to add two questions to the section for non-URers asking if they had applied, one for within the department and the other for UROs outside of the department. Another interviewee mentioned that they conducted research for the challenge of it and so we added that to the list of reasons for conducting research as it had not been present in the literature.

In preparing the survey, we devised a short definition of UR to ensure that all students were answering whether they were a URer or non-URer with a common definition. The following is that definition presented to the students:

For this survey, we’re considering [“undergraduate research” to be] any research experience outside the classroom based in science, engineering, technology, or math. If you have had more than one experience, please read the questions carefully to ensure you answer them correctly. You must have had a mentor for the duration of the experience who helped to guide your project. This mentor could have changed and you could have had more than one mentor; mentors include such people as PIs [Principal Investigators] on your research project or graduate students working with you in the lab.
You may have earned credit, been paid, or simply volunteered. This experience could have taken place anywhere, on or off campus.

After several weeks of discussion and literature review, we determined that we had an acceptable first draft of the student survey. Then we interviewed three more students as they answered the survey, asking for their thoughts and any additional answers they wanted to choose. The survey took them approximately thirty minutes to complete, with discussion. For example, one interviewee noted that a good source of information about UROs could be research seminars such as Beyond Boulder. With input from the interviews and the input of another member of the PER@C group, we finalized the survey.

In administering the student survey, we sent a link and introduction text to the physics department’s undergraduate coordinator and asked her to send it to students registered in the department as Physics or Engineering Physics majors who were also enrolled in physics classes in the Fall 2014 semester. Speaking directly to the students was difficult as many of the largest classes contained mostly non-physics majors and so a targeted effort to increase participation was only made to upper-division courses via a single PowerPoint slide sent to the professors of those classes. This slide and two reminder emails did not increase participation and so the survey was closed.

For the faculty survey, we mostly used the literature to determine the questions we wanted to ask because we could not interview many faculty members; this lack of interviewees was both due to time and the difficulty of asking already-busy faculty to engage in both an interview and a survey. In order to ensure measurement validity, we provided survey participants with a definition similar to the one presented to the students, which was edited to refer to mentoring instead of conducting UR, as below:

For the purposes of this survey, we’re considering any research experience outside the classroom based in science, engineering, technology, or math as being “undergraduate research.” You must have had an undergraduate student within your research group that you, your postdocs, or your grad students mentored. You could have had more than one
student; they may have been CU students or from other universities/schools. This experience could have taken place anywhere, on or off campus.

Once we had a draft of the survey completed, we did two faculty interviews since there was a very limited pool of survey participants. Since there were only about fifty faculty that the survey would be sent to, we did not wish to overburden the small sample with interviews and decrease participation in the survey as a result. One change we made due to feedback from these faculty members was in adding an “adjunct professor” to the list of titles the faculty members could choose from. These interviews showed us that our survey was acceptable and so we prepared to send it to the faculty once the semester began.

For the faculty survey, Dr. Lewandowski sent an email to all physics department faculty members including some associated with JILA. She also spoke briefly at one of the weekly faculty meetings to impress the importance of the survey on the faculty, which we believe improved response rates; since she spoke to them before sending the survey to the faculty members, we do not know if her request influenced participation.

Comparison Populations

We want to compare student and faculty responses to several questions in order to determine if there were specific population differences in survey responses. Since there were not enough student responses for generalizations, these comparisons are strictly based on a limited survey sample and may not hold true for the entire student population, especially for non-URers.

For students, we used three comparisons: by undergraduate research experience, by major, and by years of postsecondary education at CU-Boulder. We first asked students to self-report if they had conducted research according to the definition given; this served to divide those with research experience (URers) from those without (non-URers). Also, we asked them to indicate their major; all but two were either EPEN or PHYS, so we used those two majors for comparison. The two who were not EPEN/PHYS must have only recently switched out of the major or were planning on dropping it because the email was only sent to registered PHYS or

* JILA Science is a joint research institute between CU-Boulder and NIST. Find out more here: https://jila.colorado.edu/about/about-jila
EPEN majors. Finally, we asked students how many years they had studied at CU-Boulder specifically and how many years they had been in postsecondary education overall; if these two numbers were different, they were considered “transfers.” There may be some issues with comparing in this way because students who changed majors but never went to a different college would not be considered “transfers,” but we have no way to speak to how many participants may have switched. This allowed us to compare students “new” to CU-Boulder to “veterans” of the school and transfer students to non-transfers.

We ultimately decided to prioritize analysis by years at CU-Boulder because some transfers may have come to CU after one to three years at community college or could be continuing their education as adults and we were unable to separate these populations. The important aspect of this analysis was to determine if time spent at CU-Boulder affected how likely students were to answer the survey in a certain way; we were not particularly interested in determining how transferring affected students’ access to UR. The only time transfer and non-transfer students were compared was in determining participation rates in UR.

We compared faculty in three ways: by years mentoring and by research type. We asked how many years they had mentored URers to group more-experienced (senior; ≥10 years of mentoring) and less-experienced (junior; <10 years of mentoring) mentors. We did compare by research type (experimental or computational/theoretical). Though we could not compare by area of research (e.g., plasma) due to the small size of those groups, we did ask for an idea of the sizes of the various research groups on campus. As the final comparison point, we asked for their title (e.g., Assistant Professor).

Measures

For our analysis, we relied on a variety of statistical tests to answer our research questions. The most common, for comparison purposes, was the Mann-Whitney U test. For single-choice or multiple-choice questions, we used a response rate test and sometimes a standard average. Due to the small sample size, it was impossible to analyze the comments made on certain questions in any statistical way and so these comments were used to illustrate certain points or to capture reasoning behind a survey participant’s answer.
For the comparison of sample populations, we used the Mann-Whitney $U$ test (MW test) as it is a nonparametric test. It is commonly used to test the null hypothesis (that our samples were the same) and to determine whether one of those populations tended to have larger or smaller values than the other. To implement the MW test, we used Excel and the Real Statistics Resource Pack software (Release 3.2.2), an Excel add-on designed by Charles Zaiontz and available online. Throughout our analysis, we used a significance factor $\alpha$ of 0.05. This corresponded to a 5% or less chance that the data was random. Mann-Whitney tests can be done in a one or two-tailed scheme. We chose to use the two-tailed method as we were unsure as to which direction each sample should lean and could not discount a positive or negative correlation for most of the questions. The MW test was used along with means of the responses to show the differences between the average responses of different populations and if that different was significant.

The original Likert scale for the measures analyzed with the MW test included six answers; we then broke this down into a three-point scale as shown in Figure I. Such a break-down enables us to make conclusions about familiarity without parsing the difference between “slightly” and “moderately” familiar, for example.

<table>
<thead>
<tr>
<th>Not familiar (-1)</th>
<th>Neutral (0)</th>
<th>Familiar (+1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never heard of it (1)</td>
<td>Slightly familiar (3)</td>
<td>Very familiar (5)</td>
</tr>
<tr>
<td>Not familiar (2)</td>
<td>Moderately familiar (4)</td>
<td>Participated in it / Extremely familiar (6)</td>
</tr>
</tbody>
</table>

Figure I. Breakdown of familiarity scale used in analysis.

To calculate a response rate for one option or answer on a single- or multiple-choice question, we counted how many of the students chose each option and divided by the number of students who had responded to that question at all. Response rate allowed us to determine which answer(s) were likely to be popular among groups or overall. For a standard mean, we counted how many options each student chose and averaged the number of responses per student. Standard means allowed us to determine if there were differences in how many options students were choosing.
For both surveys, we provided space for text answers to several questions. We did not plan to analyze these in detail. Instead, they provide commentary on responses and expose some traits of UR that is unique to CU-Boulder’s Physics Department.

Some questions we did not analyze after the survey results returned for several reasons. Due to the homogeneity of physics students and our small sample size, we were unable to compare students by gender and race. Because of the small sample size of non-URers, particularly those who decided they may not or definitely do not wish to do UR, we were also unable to analyze the responses to 5.2 (asking if they wanted to conduct UR) beyond simply “Yes,” “No,” or “Maybe.” For the faculty survey, due to the very small number of faculty members who had never mentored URers, we were unable to analyze question 3.1 (asking why they had not mentored).

Measures Analyzed with Mann-Whitney U Test

Faculty and Student Awareness of Programs, Groups, and Labs

In order to ascertain where recruitment and support for UR would be most useful, we created measures which asked students what research programs and groups they were aware of in survey questions 2.1, 2.2, and 2.3. To understand how faculty might recruit mentees, we asked what research-related programs and groups they were aware of in survey question 2. The programs and groups are named in Figure II and more information is available in Appendix C.

Both populations were given Likert scale familiarity questions about these programs. To analyze how UR and time at CU affected students’ likely familiarity with support systems and UR funding and opportunities around the Boulder area, we compared results of the survey between URers and non-URers, between students with more than two years at CU and those with two or fewer years at CU, and between students of different majors. In addition, students were asked questions about their awareness of physics sub-disciplines such as high energy physics. Students were able to choose one answer from a Likert familiarity scale.
Characteristics of Undergraduate Research Experiences

To compare a student’s ideal URE with what faculty members commonly offered, we asked faculty and students a related pair of questions concerning what characteristics of UREs, such as length, were common (for faculty) or preferred (for students). This question was asked as a bipolar chart, with two opposite characteristics (e.g., short (1 semester or 1 summer) vs. long (more than one semester or summer)) listed on opposite sides of a five-point scale. This scale differed for students (preference) and faculty (frequency); see Appendix A, question 6, and Appendix B, question 4.5, for details.

We originally asked both groups about “individual” vs. “group” projects, but upon reflection realized that there were multiple ways to interpret this question; a “group” project may be one in which a team works on the same problem or project, or it may be one in which one person works on a project in support of a larger group problem. Thus, in our analysis, we did not include the data for “Individual project versus Group project” responses.

We used the MW test to compare mean results between student groups and between faculty groups in order to determine if there were any significant differences separately. Then,
we compared the mean responses between students and faculty and used a Mann-Whitney test to determine if there were significant differences between the two.

*Student-Reported Importance of Characteristics of Undergraduate Research Experiences*

We also wanted to know what was important to a student when they considered what kind of URE they wanted. Question 7 on the student survey asked students to rank the characteristics of a URE (e.g., length of the experience) in importance from one (most important) to six (least important).

*Student Statement Agreement*

Using the literature, we developed several statements, such as “I know about my professors’ research projects,” to determine how students felt about UR and faculty research, closely related topics. These statements are listed in questions 8 and 9 on the student survey; students used a Likert disagree-agree scale of five points plus an “N/A” option to answer them. As with our awareness question, this five-point scale was collapsed into a three-point scale: disagree (-1), neutral (0), and agree (+1). “N/A” responses were not included in the breakdown.

*Faculty Ideas about Important Student Traits*

We wanted to know how faculty determined which students to hire as undergraduate researchers and so asked what traits they look for in prospective mentees. Question 4.6 on the faculty survey asked about student traits (such as years to completion of degree and GPA) with a five-point Likert unimportant-important scale.

Measures Analyzed with Response Rates and/or Standard Means

*Student Awareness of Non-institutional Labs*

Since non-institutional labs also hire undergraduate researchers, students were asked about their awareness of nearby labs such as the National Institute of Standards and Technology (NIST). For this measure the students simply checked one or more boxes next to the names of the labs they knew offered UROs. Thus we analyzed this question in order to determine if there were popular and unpopular labs and if there were differences between certain student groups in terms of how many labs they were familiar with.
**Student Sources of Information about Undergraduate Research**

In order to determine how students actually hear about UROs are CU-Boulder, question 3 asked students the methods by which they received information. We gave them a list of possible answers which we developed through literature analysis and interviews and offered both an “Other” option with a text box and an exclusive “I am not aware of any of the above opportunities” as a last option. If that last option was checked, none of the other options would be able to be chosen. They could choose as many answers, besides the last, as they liked. Our analysis of question 3 included two methods: response rate and standard means. Response rate allowed us to determine the most often used source(s) of information for students overall and by groups. Standard means allowed us to determine if there were differences between groups in how many sources of information they were likely to use in obtaining information about UROs.

**Student Ideas about the Duties of Undergraduate Researchers**

Despite the definition provided to the students, which carefully avoided any mention of actual activities undertaken by the researchers, we knew from the literature that students would have varying ideas about what students conducting UR actually do as part of their research experience. So we offered them a list of eleven options (two of which were discarded during the analysis phase) and asked them to choose between three and six of them to describe the main characteristics of UR at CU-Boulder in questions 4.1 (for URers) and 5.1 (for non-URers). The last two in both lists (two “get mentoring” responses) were removed from the analysis because they were, on inspection, not actually duties that the undergraduate undertakes.

**Student Researcher Data**

For students who indicated they were doing or had done undergraduate research, we asked several questions simply for categorization purposes. Some of these only required response rate computation: questions 4.2, 4.3, 4.4, 4.5, and 4.9 were analyzed thus. For questions 4.6 and 4.7, we used both response rate and standard mean analysis. Some students left comments in appropriate textboxes in this section but there were not enough to generalize their responses.
Student Non-Researcher Data

Despite being unable to analyze beyond the three choices for question 5.2, non-URers still provided some good data. For questions 5.3 and 5.4, we only used response rate analysis to determine how many students were applying to UROs and not conducting UR; the comments on these were so few that, again, we were unable to generalize from them. Additionally, question 5.5 provided information about what the students were doing during their summers and was only analyzed with response rates.

Student Demographic Data

Questions 11, 12, 13, 14, 15, and 16 involved demographic data such as major, plans for after completing a degree, and gender. We analyzed questions 11 (major), 14 (plans for after graduation), 15 (gender), and 16 (race) on response rate. For questions 12 (years at CU-Boulder) and 13 (years in postsecondary education), we used response rate and standard mean. We also used 12 and 13 to find transfer students and compare their UR participation rate to non-transfers’.

Faculty Mentor Data

We wanted to understand what faculty do as undergraduate research mentors and why they mentor. Questions 4.1, 4.2, and 4.11 asked faculty about their commitment to mentoring; question 4.3 asked why they mentored with a list of reasons (they could choose up to four) and an “other” option. For past mentors, we included question 4.4 asking them why they were not currently mentoring, allowing them to choose up to five options and/or write in their own. In order to determine the role of secondary mentors such as postdocs and graduate students, we also asked in question 4.8 who was primarily responsible for mentoring the URers on the team, and allowed faculty to choose any/all of these options. In question 4.9 and 4.10, we asked what changes they would have made to their most recent mentoring experience; they could choose up to three from the list in 4.9 as well as write in their own answers in 4.10.

Faculty Demographic Data

We asked faculty some demographic questions such as 8 (field of research), 9 (characterization of research), 10 (title), and 11 (gender). For question 9, faculty members were
asked to check one, two, or three boxes indicating if they considered themselves experimental, computational, or theoretical research faculty. Some chose only experimental while others chose theory and computational. The number to choose strictly theory or computational was exceedingly small, so for comparison purposes, these two types of research were combined since they are strikingly similar. Some faculty members, however, chose to check all three of these boxes. These presented a problem as they did not fit either category easily. Based on discussion with faculty members, we assigned these to experimental. As with students, the sample size was too small for meaningful comparison between men and women.

Text Comment Analysis

Many of the students and faculty provided some of their own answers when prompted. While there were usually not enough comments to generalize them, we were able to use them to make commentary on certain responses. Some of the comments, for example, mentioned issues specific to CU-Boulder that had not been in the literature or in the interviews; this was more common with the faculty survey than with the student survey. Most of the comments, therefore, will be presented as reasoning for certain students’ responses or to introduce a certain difficulty unique to CU-Boulder.

One of the main features of the faculty survey was a question, one for current mentors and one for non-mentors and past mentors, about how the department could help the faculty to mentor more undergraduates. There were enough responses here for some common threads to emerge, but these were fairly vague and very general, such as issues with money that varied between faculty members. We discuss these comments either with the discussion or, if they do not pertain to a specific response, in the second to last part of the Results and Discussion section.

Results and Discussion

Below, I present the results from the survey using the methods described above. First, I make clear how the survey sample compares to the department population. I explain how the students and faculty were categorized in order to make comparisons between different groups. Next, I propose answers to our five research questions based on the results from both the student
and faculty surveys. Discussion of the relevance and nuances in the data as well as participant comments is presented along with the numerical results. Then I provide a brief synopsis of the results and discussion herein before moving on to making recommendations for changes to the survey.

Demographic Comparison

In order to compare the demographics of survey participants to those of the department as a whole, I describe the overall demographics of the Physics (PHYS) and Engineering Physics (EPEN) students within the Physics Department using two non-survey sources of data: private communication with department undergraduate coordinator Kristen Apodaca and data from the Office of Planning, Budget, and Analysis (PBA). These data speak to the demographic makeup of “physics students” (i.e., both PHYS and EPEN majors) and physics faculty according to several dimensions. For students, these dimensions are: a) major, b) participation in research, c) race/ethnicity, and d) gender. For faculty, we use: a) gender and b) mentoring undergraduate researchers. Through comparison of survey participants to the broader population of physics students and faculty along these metrics, I identify and discuss important limitations of the present study. Also, using data gathered solely from the survey, I provide the basis for comparison between groups of faculty members and between groups of students.

Demographics of Department’s Student Population

As of the beginning of the 2015 semester, according to the undergraduate coordinator in the Department of Physics at CU-Boulder, there were 577 Physics (PHYS) and Engineering Physics (EPEN) majors registered with the department, 464 of whom were enrolled in classes during the Spring 2015 semester. At the end of the Fall 2014 semester, all PHYS and EPEN students were asked to indicate on their advising sheet, required for registration for the next semester, whether or not they were currently conducting UR. Only 394 of those students returned advising sheets. This breakdown is available in Table I below.

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* The PBA gave this data to Joel Corbo, a physics education researcher in the PER@C group. He shared an anonymized set of data with me for the purposes of comparison with my own data.
Table I. Information from department registry, enrollment data, and fall 2014 advising sheets. The “Registered” and “Enrolled” columns use data from the department registry. The last two columns use data from the advising sheets.

<table>
<thead>
<tr>
<th></th>
<th>Registered</th>
<th>Enrolled</th>
<th>Current URer</th>
<th>Not current URer/Non-URer</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPEN</td>
<td>152</td>
<td>26%</td>
<td>139</td>
<td>30%</td>
</tr>
<tr>
<td>PHYS</td>
<td>425</td>
<td>74%</td>
<td>325</td>
<td>70%</td>
</tr>
</tbody>
</table>

Demographics of Student Survey Sample

Of the 76 students who completed the survey, 46 were engaged in or had done undergraduate research. Unfortunately, despite efforts to diversify the physics field by various institutions including CU-Boulder, the vast majority of students were Caucasian (84%) and male (83%). Our sample (n=76) is not large enough to make claims about differences in UR experiences among students from majority groups (white and/or male) and students from underrepresented groups (under-represented minorities (URMs) and/or women). While we did not reach as many students as we had hoped, especially among non-URers, the comments and data from the survey participants were very useful and illuminating.

We did analyze research participation between URM (Under-Represented Minorities) and non-URM students as well as men and women. Our sample size for URMs (n=4) was too small to make any significant conclusions. There was no significant difference (p = 0.9) in research participation rates between men (60%, n=62) and women (58%, n=12).

Of those forty-six students with research experience, a third had spent two or fewer years in college education and the rest had more than two years in postsecondary education. We did differentiate between years at CU-Boulder and years at any college or university to account for transfer students and second-degree students (see Figure VI). By comparing transfer and non-transfer students, we found that there was a statistically significant difference (p = 0.03) in participation rates in UR.
From the survey data, it was clear that there were three significant population comparisons to make, particularly when awareness was concerned (see Figure II). We compared students who reported they had research experience (URers) with those who did not (non-URers) in order to test if involvement in research significantly impacted a student’s likely survey responses. Due to the inherent similarities in their course work and degree programs, we also compared PHYS to EPEN majors to determine if different affected likely survey responses. Finally, we compared students with two or fewer years at CU to those with more than two years at the institution in order to determine if time at the school affected students’ likely responses. We did not compare transfer and non-transfer students, however, as transfer students had a range of one to three years at CU and thus we may have ended up comparing a junior transfer to a freshman non-transfer student.

Figure I. As shown, non-transfer students were significantly more likely to be researchers than transfer students ($p = 0.03$).
Figure II. There were three major divisions between the students in our sample.

Comparison of Student Demographics

Sixteen percent (76/474) of the department’s student population responded to our survey. On the survey, 23 PHYS (43% of known URers in the major, according to data from the advising sheets) and 15 EPEN (41%) students reported being currently involved in research. Seven students had finished their research by the time of the survey. These seven students made up 15% of the URers in the survey sample. Since we have no data about past researchers from the department, we cannot say whether this is representative of the population or not.

In our survey, URers were over-represented overall (Table II). This was expected, however, as the survey email was titled “Undergraduate Research Survey” and so some students without research experience may have deleted the email without reading the body of the email which indicated that both URers and non-URers were encouraged to take the survey. For future
iterations of the student survey, this issue may warrant a change in the title of the email and survey.

**Table II.** Comparison between survey sample data and departmental population data.

<table>
<thead>
<tr>
<th></th>
<th>EPEN</th>
<th>PHYS</th>
<th>Current URers</th>
<th>Past URers</th>
<th>Female</th>
<th>URM(^i)</th>
<th>Total(^ii)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop.</td>
<td>135</td>
<td>28%</td>
<td>346</td>
<td>72%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sample</td>
<td>32</td>
<td>43%</td>
<td>41</td>
<td>55%</td>
<td>38</td>
<td>50%</td>
<td>7</td>
</tr>
</tbody>
</table>

Some data may not add up to 100% due to missing data from either the advising sheets or survey.\(^*\)

\(^{i}\) Under-Represented Minorities, including Black, Latino/a, and Native American students.

\(^{ii}\) This is not the total of the row but the total in the enrolled department population or in the survey sample. It was used to calculate the percentages.

As shown in Table II, the survey sample was overrepresented by the EPEN major, splitting the survey sample more evenly than the department population. Using a Chi-Square test, we found that the overrepresentation of EPEN majors is statistically significant (Pearson’s p-value of 0.00622). This could be because EPEN majors currently doing UR are overrepresented in the department (27% EPEN vs. 20% PHYS). However, we do not know for certain the cause of this overrepresentation of EPEN majors in our survey. The survey and population demographics are not statistically different when comparing the number of URMs or when comparing the number of women.

**Demographics of Department’s Faculty Population**

Of the eighty-plus faculty and staff in the Department of Physics at CU-Boulder, there are fifty tenured and tenure-track professors plus a few instructors and research faculty. The survey was sent to fifty-seven faculty members.

\(^*\) We drew the data for the majors from the department registry; for the research status, from the advising sheets; for the gender, from personal communication with the undergraduate coordinator; and for URMs, from the Office of Planning, Budget, and Analysis (via Joel Corbo).
**Demographics of Faculty Survey Sample**

Forty-four faculty members completed the survey (77% of the target population). Like students, we asked faculty members if they were mentors in undergraduate research; 28% had mentored in the past and 63% were currently mentoring undergraduate researchers (only 9% were not mentors). We made data comparisons between experimental and computational/theoretical faculty and between junior and senior mentors (see Figure VIII).41

**Figure III.** Faculty members were compared by research type and mentoring experience.

In terms of research type, we had twelve computational/theoretical researchers (called “Comp/Theory” for brevity) and thirty experimental researchers. This split is not particularly even, but as these research types are very different, the comparison is still useful and interesting.

The faculty mentors ranged from one to thirty-six years of mentoring experience. These responses group the faculty members fairly evenly into those with less than ten years’ experience (“junior” mentors) and those with at least ten years’ experience (“senior” mentors). Ten years is also a considerable amount of experience, making a natural turning point between less-experienced and more-experienced mentors.

Like students, faculty members were mostly male (83%). Thus, we did not compare men and women. To protect anonymity, we did not ask faculty members to indicate their racial or ethnic heritage. In order to determine relative sizes of the campus research groups, we also asked mentors to identify their area of research. These data are available in Table III. They were able to choose as many of the options as they liked; 79% chose only one, 14% chose two, and 7% chose
three. None chose more than three. This matches fairly well with the areas in which URers conducted research; the largest single employer of URers was AMO, the same as for faculty. Very few faculty work in nuclear physics and geophysics. We did not ask faculty members if they worked with NIST or other Boulder area labs off-campus and so cannot compare that to students’ involvement with those labs.

Table II. Faculty members reported that they were in a variety of research areas, though the most popular were AMO and Condensed Matter (faculty could choose more than one). Students reported that they worked in a variety of places, including off-campus labs, and were able to choose more than one.

<table>
<thead>
<tr>
<th>Area of Research</th>
<th>% of Faculty</th>
<th>% of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astrophysics and Planetary Sciences (Space)</td>
<td>7%</td>
<td>4%</td>
</tr>
<tr>
<td>Atomic, Molecular, and Optical Physics (AMO)</td>
<td>28%</td>
<td>40%</td>
</tr>
<tr>
<td>Biophysics</td>
<td>9%</td>
<td>4%</td>
</tr>
<tr>
<td>Chemical Physics</td>
<td>7%</td>
<td>2%</td>
</tr>
<tr>
<td>Condensed Matter</td>
<td>28%</td>
<td>16%</td>
</tr>
<tr>
<td>Geophysics</td>
<td>2%</td>
<td>0%</td>
</tr>
<tr>
<td>High Energy (Particle)</td>
<td>21%</td>
<td>7%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>Physics Education Research (PER@CU)</td>
<td>7%</td>
<td>13%</td>
</tr>
<tr>
<td>Plasma</td>
<td>7%</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>7%</td>
<td>53%</td>
</tr>
</tbody>
</table>

Table III. Faculty members reported that they were in a variety of research areas, though the most popular were AMO and Condensed Matter (faculty could choose more than one). Students reported that they worked in a variety of places, including off-campus labs, and were able to choose more than one.

As shown in the Table III, large numbers of faculty in a particular physics subdiscipline does not necessarily correspond to a large number of students conducting UR there. Some students worked in off-campus labs such as the Center for Astrophysics and Space Astronomy (CASA) or in other institutions like CU-Boulder’s Chemistry Department or the School of Education. Faculty “Other” responses included physics fields such as photonics and the history and philosophy of science.

Comparison of Faculty Demographics

Due to the lack of department data about faculty gender, research type, and field of research, we could not compare our sample with the population. Additionally, though racial and ethnic data was available, our survey did not ask this question of faculty and so we could not compare in that mode, either. However, with a response rate of 77%, we can say that our data should be representative of the population as a whole.
Awareness of Research Programs and Groups

Our first research question asked what students and faculty were aware of in terms of research-related programs, labs, and groups. We wanted to understand where efforts to increase both student and faculty participation in undergraduate research could be best made. Below, I present the results from several awareness-focused questions from first the student and then the faculty surveys.

Student Awareness of Campus Programs and Groups

We asked students how aware they were of a variety of campus programs and groups. First, we asked about several programs that offer funding and informational seminars. In order to determine what programs or groups attracted students to them, we asked students to indicate if they had participated in each group or program. As shown in Figure IV, URers were generally more likely to participate in research programs than non-URers. This is, of course, true for UROP, NSF REU, D-LAP, and BOLD, which only work with URers because of the nature of those programs. The colloquium, while not particularly directed at undergraduate students, is a draw due to the free cookies and refreshments before the talk and because most of the faculty, postdocs, and grad students attend, leaving the lab and, by invitation or not, drawing the undergraduate researchers with them.

YOU’RE@CU provides UREs for students, so it is startling that a self-reported non-URer claimed to participate in YOU’RE@CU. This student commented that they had taken part in YOU’RE@CU but did not consider helping a graduate student with his or her research to actually be UR and so claimed to be a non-URer despite the definition presented at the beginning of the survey.
Figure IV. Students participated in a variety of programs. Only URers could have participated in YOU’RE@CU, UROP, NSF REU, D-LAP, and BOLD.

When comparing URers to non-URers, we found, in many cases, that URers were significantly more aware of some programs, with a p-value less than 0.05 (see Figure V). EPEN majors were significantly more aware of BOLD (p=0.0001) and D-LAP (p=0.01) than their PHYS peers; we expected this as those are programs that assist engineering students. Students who have spent more than two years at CU-Boulder were significantly more aware of NSF REU (p=0.006), the department colloquium (p=0.03), Beyond Boulder (p=0.003), and CU Prime (p=0.02) than students with 2 or fewer years at the university. NSF REUs are available to all students but typically send them away from their college and students may not feel comfortable in leaving the university early in their education. It also requires some mentoring or self-motivated searching to discover the NSF REU program and to apply for it, which new students may not have had the opportunity to develop. The colloquium is typically targeted to graduates and faculty, but undergraduates doing research may have more opportunities to hear about and attend the talks. Beyond Boulder and CU Prime both invite undergraduates, URer and non-URer alike, to attend their sessions, but since both deal primarily in “beyond the classroom” topics, they may not be as appealing to younger students who feel that they do not know enough physics to attend and/or are not as concerned with their post-baccalaureate plans.
Figure V. URers were significantly more aware of several programs, as indicated by the p-values less than 0.05. For other programs, the two groups were similarly unfamiliar with them (black p-values greater than 0.05).

For the values close to neutral, we looked at histograms to assess the distribution of the responses. Non-URers were neutral for CU Prime and Colloquium; both distributions were bimodal so that some were familiar with those programs while others were not. Every “neutral” answer had a bimodal distribution except for how familiar EPEN majors were with BOLD; that distribution was flat across -1 (unfamiliar), 0 (neutral), and +1 (familiar).

When viewed in conglomerate, both URers and students with more than two years at CU-Boulder were aware of more programs than their non-URer peers and students with two or fewer years at CU-Boulder, respectively (see Figure VI). This was true for both EPEN and PHYS majors. One interesting point to notice is the number of non-URers who were not aware of any of the named programs. Very few students were aware of all nine, but the average for URers and the more experienced students was higher than that for the non-URers and less experienced students, respectively. This is more evidence that research experience and time spent studying at the university can improve a student’s familiarity with campus resources.
Student Awareness by Research Experience

As shown, there is a gap between URers and non-URers and between students with two or fewer years and those with more than 2 years at CU in terms of how many programs they were aware of (defined as a score of 0 or +1 on the three-point scale).

Student Awareness of Physics Subdisciplines and Labs

Next, we asked students how aware they were of physics research groups in the department. We listed ten physics subdisciplines in which researchers at CU-Boulder work and asked students how aware they were of those research groups on a six-point familiarity Likert scale. URers were significantly more aware of some groups, like AMO, but on the whole, students were mostly unaware of these groups (see Figure VII). There were no significant differences by major. There was only one significant difference between students by years at CU-Boulder; students with more than two years at CU-Boulder were significantly more aware of the nuclear research group (p=0.009) than students with two or fewer years. This could be due to the nature of nuclear physics; it is not typically taught in the types of courses that students with two or fewer years at CU would be likely to take.

As before, we examined the distributions for mean answers near 0. Most URers were neutral regarding their awareness of PER. EPEN majors also had a spike at 0 (neutral) about their awareness of AMO. These distributions indicate that while some students were familiar with these disciplines and some were not, the majority were fairly neutral in their familiarity.
Students were, on the whole, mostly unfamiliar with the physics research groups at CU-Boulder. URers were significantly more aware of AMO, Particle, Condensed Matter, and PER than their non-URer peers.

Instead of a Likert scale for students’ awareness of other labs in Boulder, such as NIST, we asked students to mark a checkbox next to labs they had seen advertise undergraduate research opportunities. On average, URers checked almost twice as many boxes as non-URers. Those labs provide important opportunities for students looking for jobs outside of academia or who cannot find an opportunity with a faculty member.

Faculty Awareness of Campus Programs and Groups

For the sake of brevity, we only asked faculty members about ten campus programs and groups. Faculty were most aware of NSF REU, Independent Study, Physics Honors, and UROP. Those programs offer “financial” (either in course credits or money) support for undergraduate researchers, allowing the faculty member to mentor them without spending his or her own grant money. Faculty were generally least knowledgeable about the BOLD Center and D-LAP, programs for engineering physics students, and YOU’RE@CU, a young program with a focus on graduate students as mentors. There were no significant differences in awareness by research type, years mentoring, or title.
Figure VIII. Faculty members’ participation in groups and programs was higher for those that provided student funding/support (such as UROP). These are only the extremes – “never heard of” and “participated in” – and not the overall familiarity.

Over half of all faculty participated in independent study, NSF REU, and UROP – sources of undergraduate research labor at no or little monetary cost to them. Just over 40% also “participated” in Physics Honors, a class that gives URers credit for their research and offers presentation opportunities to prepare for a thesis defense. Fewer faculty had participated in PROS (22%), Beyond Boulder (15%), and CU Prime (5%), groups that would allow them to present their research to interested physics graduate and undergraduate students. While these seminars might serve to find mentees, they would not provide funding assistance.

Most faculty members had not heard of the BOLD Center (71%) or the YOU’RE@CU program (78%). These are programs housed in the Engineering Center, quite distant from the Duane Physics building in which the faculty work and thus not as visible to them. The YOU’RE@CU program also does not typically work with faculty members but rather with graduate students for mentoring purposes.

In conclusion, we found that, as we would expect, URers were typically more aware of research-related programs and labs than were non-URers. However, since URers are already involved in research, we want to increase awareness for non-URers. Students with more than two years at CU-Boulder were also typically more aware of these programs than were students
newer to the campus, indicating that time spent at the university is a valuable aspect of a student’s education and increases their familiarity with campus resources. Faculty members were most aware of and participated most often in programs that offered funding or other support for undergraduate researchers.

Why Faculty Members Mentor Undergraduate Researchers

We wanted to understand why faculty members offer UROs in the Physics Department when the literature shows that UR is a tasking process and mentoring consumes valuable time. By beginning to understand the motivations to offer UROs as well as the changes they would make to their most recent mentoring experience, we could begin to address where faculty members could make the best use of department support.

To make a claim about who actually mentors undergraduates, we asked faculty members who was primarily in charge of mentoring the students and allowed them to choose as many answers as they liked. Almost 90% said that they were primary mentors, including all Comp/Theory mentors (see Figure IX.) Only 18% of comp/theory researchers had graduate students and/or postdocs mentoring compared to 48% of experimental researchers, but this difference was not statistically significant ($p = 0.2$). Experimental faculty may have access to more graduate students or may have larger research teams than do comp/theory faculty, which future research could determine. Additionally, none of the faculty members reported that the students did not receive any mentoring, indicating that mentoring is always part of undergraduate research in the department.

![Figure IX](image_url)

**Figure IX.** Faculty mentors were asked who primarily mentors the undergraduate researcher(s) in their research group.
For an idea of the commitment that mentors undertake, we asked them two questions. When asked how many undergraduates they typically mentored each year, 31% of faculty members reported that they mentored irregularly, 52% mentored 1-2 students a year, 17% mentored 3-4 URers a year, and none mentored more than 4 students a year. Depending on how many hours a faculty mentor puts into their undergraduate researcher, mentoring students, especially more than one, could be a large commitment in terms of time and money.

Senior mentors were more likely to mentor 3-4 students a year (26%) than junior mentors (6%). This may be because junior mentors have less time to devote to UR because they are tenure-track, because they are less experienced with their undergraduates, because they have smaller research teams, or because their undergraduates require more extensive mentoring than their senior peers. We cannot say what reason prompts this divide, however, without further testing.

Comp/Theory researchers were much more likely than experimental faculty to mentor irregularly (73% and 17%, respectively), and none of the comp/theory faculty mentored more than two students a year. This tells us that experimental faculty can mentor more undergraduate researchers and are more regular in their mentoring than comp/theory researchers.

According to the students who turned in their advising sheets, there are about ninety undergraduates engaged in research. If all of the faculty were able to mentor two students a year (either one each academic year semester or two for a full year), over one hundred students each year would have undergraduate mentoring opportunities. Using the survey data, we calculated that faculty participants mentored between forty and eighty students per year. This is only faculty at CU-Boulder, however; some URers work off-campus in labs like NIST or at other universities which could account for the number of students who reported they were currently doing research.

The second question we asked was how many years faculty mentors had mentored undergraduate researchers. The average was 11.6 ± 1.4 years with a range of 35, a median of 10, and a mode of 4 years. There were 18 junior mentors (less than ten years’ experience) and 23 senior mentors (10 or more years of experience). Of course, there may be some factor of
uncertainty since the faculty may have rounded nine up to ten or eleven down to ten years of experience. However, there were no significantly large number of mentors with ten years of experience and roughly half of faculty were on either side of this ten-year divide; there was no reason to believe such random rounding affected the results. If a faculty member averaged two students a year over those ~12 years, and only offered one-year experiences, they would be able to mentor twenty-four students; if they lived their entire career at CU-Boulder, somewhere around forty or fifty years, they would be able to mentor nearly one hundred students.

In order to determine the desire of faculty members to mentor UR, we asked those who mentor(ed) (91% of total faculty participants) why they participate(d) in UR. We asked them to check up to four boxes from a list of possible reasons (see Figure X). The top four reasons were: to offer interesting opportunities to students (86%), to teach students about the research process (55%), because they enjoy watching students grow and develop (55%), and to get help with their research (50%). There were also a variety of other choices made, but these four were clearly the most common. These top four reasons fall into two categories: teaching moments (the first three) and research assistance (the last one). Faculty members, whether or not they mentor URers, are typically expected to teach a class each semester (though exceptions can be made). Blending their teaching and research responsibilities as mentoring may be one motivation for a faculty member to teach at a research-intensive institution instead of at a non-research university.

Just over 10% reported that mentoring was expected of them, a concern brought up in previous studies. Thus, while most of the faculty do mentor undergraduate researchers, few believe that one of their primary motivations in mentoring comes from expectations of them. We did not ask who would expect them to mentor, though one could suppose students would expect mentoring in undergraduate research projects that they undertake. The department may also expect mentoring of its faculty members insofar as requiring it for an honors thesis or independent study courses.

There were no significant differences between experimental and comp/theory researchers or between junior and senior mentors. Experimental researchers checked off more of the reasons than did comp/theory researchers. Additionally, experimental researchers were
more than twice as likely as comp/theory to say that giving grads/postdocs opportunities to mentor undergraduates was one of their reasons for mentoring undergraduates (17% and 37%, respectively), though this is not a significant difference. This is another piece of evidence that speaks to who actually mentors undergraduates; graduate students and postdocs are more often part of mentoring if they work with experimental faculty than with comp/theory faculty.

Figure X. Faculty were asked why they mentor URers. There were four common answers and a variety of rarer ones.

We also asked faculty members who had mentored in the past (28%) why they were not currently involved in research and received a variety of answers, though “Other” and “Topic is too complicated for undergraduates” were the most popular choices. Those who checked “other” were given the option to write in their own response; those varied widely. Some faculty members said they did not know any potential candidates, raising a networking issue of having such an informal application system. Formalizing the application process could improve networking for faculty who teach small courses or those who do not teach at all, enabling them to put out a call for applicants either through an independent source or with the programs and groups associated with physics. Some faculty members can and do send out emails through the undergraduate coordinator to call for interested undergraduate researchers, but due to the volume of emails from the department, some students may ignore these infrequent URO emails.
Also, faculty mentors often look for specific traits in their undergraduate research mentees and sending out an email to all students may result in a response pool that is too large to handle efficiently.

We also asked mentors what they would have changed about their most recent UR mentoring experience. Close to 50% reported they would have made no change; none said that they would rather not have done undergraduate research. There were a variety of other choices, such as “chosen a longer research experience” and “chosen a different topic” that appeared, but there was no single option that even a fifth agreed on. So nearly half of the faculty were content with their most recent mentoring experience and none were so upset by it that they wished it had never happened. Both are signs that the undergraduate research in the department offers the faculty a potentially satisfactory experience.

In conclusion, we found that there were some differences between experimental and comp/theory faculty in how they conduct their mentoring but not in why they do so. While almost half of experimental researchers had graduate students or postdocs act as primary mentors, less than a fifth of comp/theory faculty reported having such mentors on their research team. Experimental faculty also mentored more students per year, typically, than did comp/theory faculty. Faculty had four reasons they agreed upon as a motivation for mentoring undergraduate researchers, with no significant differences between the groups as discussed. These four reasons fell into two categories: teaching moments and research assistance. For the third of faculty who were not currently mentoring, we asked them why not; the answers varied and the sample size was too small to make generalizations. Two comments, however, noted the difficulty of networking in such an informal application process. Finally, we asked faculty what they would have changed in their most recent mentoring experience and nearly half said they would not have made a change and no single change stood out.

Why Students Choose to Participate in UREs

To determine why students choose to do or not do undergraduate research, they answered several questions. We asked students with research experience (URers) how many years they had studied at CU before starting research and about the timing and length of their
experience. To draw some conclusions about motivation, we also asked why they chose to participate in undergraduate research and what changes they would make. For non-researchers, we asked if they would like to participate in research sometime in their undergraduate career and why or why not. We also asked them if they had applied for research opportunities and what they had done with their summer (instead of doing research). Finally, we asked both groups what they planned to do after graduating in order to compare these answers, since the literature shows that undergraduate research impacted students’ plans to go to graduate school.

We found that more than half of URers started their first research experience within two years of study at CU-Boulder (see Figure XI). Nearly 90% of all URers started before finishing their third year of studies. This shows that students typically become engaged in research before entering upper-division courses like Quantum Mechanics or Solid State. It also shows that a full two or three years of physics courses is not necessarily required to do undergraduate research. Of course, some of these students may be transfers who were only at CU during a short period of time but had actually taken many classes. We will discuss this further next. We shall revisit this discovery later once we discover what faculty claim is more common: hiring juniors and seniors or hiring freshmen and sophomores.

There is a significant difference between transfer and non-transfer URers; 7 URers were transfers and 36 were not, a Pearson’s p-value of 0.03. Thus transfers are significantly less likely to conduct UR than non-transfer students. When comparing transfer and non-transfer students, we found that half of transfer students started their first URE within their first year at CU-Boulder, compared to just over a third of non-transfer students. Only 13% of transfer students started their first URE after one year at CU-Boulder compared to 28% of non-transfers. Both transfers and non-transfers were approximately equal in distribution over two and three years of study by the time they started their first URE, though both proportions were small (about 20% and 10%, respectively). Thus we find that transfers most often find their first UREs within their first year while non-transfers tend to conduct UR for the first time with more spread about the years of study before beginning.
Almost all students reported that they plan to continue participating in undergraduate research as well (93%). This shows that undergraduate research is not like a single-semester class that is taken once before the student moves on; these experiences last longer. Since the survey was conducted at the beginning of the fall semester, students may have also claimed they were “continuing” in the sense that their project was just beginning or that it had a scheduled end they planned to adhere to. Those who did not plan to continue were in their third or fourth year of studies and so may be graduating soon.

We also asked students what semester they had started their most recent experience. They were split into 42% fall, 29% spring, and 29% summer semester (given these three choices). Thus, with the beginning of a new academic year, many students begin their URE for the first time. We did not use the year that they started for analysis as many factors can contribute to how many students are hired as undergraduate researchers each year. If students indicated that they were not continuing their research experience, we asked when they had finished. Since only seven URers were done with their project, we cannot say what semester is the typical ending term for UR projects.

There were many reasons for URers to conduct UR as given on the survey (see Figure XII). Overall, more than half of the students claimed that they did undergraduate research for
experience for graduate school and to learn research skills. These are both supported by the literature. PHYS majors were more likely to report wanting research experience for graduate school (54%) than EPEN majors (31%), though this is not a significant difference. There were no significant differences by years at CU-Boulder, either. Learning these skills is vital for students who plan to do research in their career, either as a graduate student or as a researcher for a private or public lab.

The idea that URers do undergraduate research for experience for graduate school raises an interesting question, however; is UR only for students who plan to go to graduate school and/or engage in a research career? We asked students both of these questions. Most students disagreed that UR is useful only for people who want to go to graduate school (72%) or only for people who want to be involved in research (66%). Additionally, 76% of URers and 67% of non-URers disagreed with the first statement while 68% of URers and 63% of non-URers disagreed with the second statement. Thus, most students do not agree that UR is only for students interested in graduate school or a job in research.

Very few URers (9%) claimed that they conduct research in part to make money. Some URers are “paid” by taking a class that offers course credit for their research. Those who are paid with money may not conduct UR as a means of making a living because there are easier ways to find a job than to apply for the very few UR positions. Other jobs may not require as much intellectual work, may pay better, and may require fewer hours per week (or may pay for more hours per week).

Additionally, only 11% of URers reported that an expectation to do research as an undergraduate was one motivation for conducting research. Some universities require undergraduate research of its students, such as Stanford, and while pure physics (track one) students are nominally required to do research, this requirement can be fulfilled with an upper-division lab course. For any student wishing to go to graduate school, however, undergraduate research is practically required; this expectation could be one reason for the large number of students who claimed that research experience for graduate school was one reason they conducted UR.
Figur XII. Students reported their top reasons for doing undergraduate research.

Also, we asked URers what changes they would have made to their most recent URE (see Figure XIII). Over a quarter wished they had started earlier in their undergraduate career (42%) and learned more about the research topic first (29%). More than two-thirds of students who started doing UR after two years (73%) or three years (83%) of study at CU-Boulder wished they had started earlier in their undergraduate career. Starting earlier (say, as a freshman) would be difficult for students who come to the university without a declared major, who change their minds about majors during their first or second years, or who simply do not know how important UR is, or may be, to their intended future education or career path. Learning more about a research topic would require a course or self-directed study but it is difficult or nearly impossible for a student to determine what they need to learn, especially for an advanced topic after only an introductory course or two or for an undetermined UR project. Much of the learning for a UR project comes from hands-on experience, not from reading a textbook (though often URers do read books and/or articles to orient themselves and for their honors theses).

Additionally, 27% of students said they would not have made a change. Close to half of the students who started undergraduate year before finishing their first year of study reported that they would not have made a change to their most recent URE. While students were, on the whole, less likely than faculty to have said they would not have made a change, a quarter were still satisfied enough with their most recent experience to not choose a change to make. Two
students who said “no change” made comments about any other changes they would make. One said they wished they had done more research, either in a broader set of fields or for more semesters. The other student was currently involved in his or her experience but had only been involved for a short time, but said that s/he was having “a great experience.” Additionally, like the faculty, none of the URers said they would rather not have done research.

Figure XIII. Students reported the changes they wish they could make to their most research URE. None said they wish they had not done research at all. They were able to choose up to three responses, though any student who chose “No change” would be restricted to only that response.

For non-URers, we asked if they want to do UR sometime during their undergraduate career. Most of the students (80%) reported that they did want to; some (17%) were unsure and the rest (3%) did not want to do UR (see Figure XIV). This shows that many students in the department are interested in doing undergraduate research. While there were no significant differences between majors, almost all students with two or fewer years at CU-Boulder (92%) reported that they wanted to do research compared to only a third of those with more than two years at CU-Boulder.
Non-URers reported if they wanted to conduct undergraduate research sometime in their undergraduate career. There was a difference between students with more than two and with two or fewer years at CU-Boulder.

Using their answers to the previous question, we queried students as to why they would or would not (or were unsure about) do UR sometime in their undergraduate career. Due to the small numbers in the latter two categories (No and Maybe), we could only analyze the responses from those who did want to do research. Over half claimed that they wanted to do UR for research experience for graduate school (60%) and to learn research skills (68%); these are the same reasons as URers reported for why they conduct research. This tells us that non-URers would choose to engage in UR for some of the same reasons as URers, indicating that non-URers have some idea about why to do UR that matches with those who actually conduct UR. We could not compare students with over two years and fewer than or equal to 2 years at CU-Boulder because there were only two respondents in the first category. There were no significant differences in reasoning between majors.

Some of the reasons for being undecided about doing UR sometime during an undergraduate career included being uninterested in research at the moment, a lack of knowledge about available opportunities and how to get involved, and a lack of self-efficacy. To address the first concern of non-URers, introductory and first-year classes could provide some guidance and explanation about what research entails and who benefits from research. For the
second concern, groups such as CU Prime and PROS can do an admirable job of presenting information and opportunities to students, as do emails from the undergraduate coordinator, but the third concern may keep students from either attending or acting on the information at those sessions. Building self-efficacy can be a goal of introductory lab courses to ensure students feel comfortable approaching faculty mentors and applying for UR positions.

In order to determine if students were applying for opportunities and simply not getting them, we asked non-URers if they had applied both within and outside of the department. Most students had not applied, including 92% of students with two or fewer years at CU-Boulder and 83% of students with more than two years at the university. We asked students who had applied if they could elaborate. One had been turned down; one had not heard back. A third had actually been accepted into a UR program but did not consider his or her experience helping a graduate student as proper “undergraduate research,” despite the definition presented at the beginning of the survey.

Of course, the word “apply” can have various contexts. In the informal application process in the department, “apply” could include anything from expressing interest to a class professor to actually presenting a resume and cover letter to a prospective mentor. Students may not have answered this question with the former “application” method in mind, only considering the latter and/or when they had responded to a call for applicants.

Additionally, to explore what students were doing with their summer time if not undergraduate research, we asked non-URers what they did during the summer of 2014. Most (83%) of non-URers had a job, including 50% with a summer-only job not related to physics, 30% with a continuing job not related to physics, and 3% with a continuing job related to physics. None of the students had a summer-only job related to physics (like, for example, a summer UR program). Over three-quarters of physics students were not engaged with physics in their summer job; this could be an issue of income, opportunity, and/or self-efficacy.

Another third of non-URers traveled and about a tenth took classes. Two thirds of the non-URers only chose one of the available options; 27% chose two and 7% chose three. Students
who chose more than one option may have had a job while taking classes or may have traveled for part of the summer while working or taking classes for the other part; there is no way to differentiate these differences.

Finally, we asked all students what they planned to do after completing their undergraduate degree. Over half wanted to go to graduate school or professional programs in physics. This desire was not different between URers (58%) and non-URers (57%), contrary to other studies showing that UR influenced student’s decisions to go to graduate school. Since graduate school experience is one reason students want to and do do UR, we would expect that non-URers would be less likely than URers to want to go to graduate school in physics. Since most non-URers want to do undergraduate research, however, so perhaps graduate school is appealing to students who already want to do UR more than those who know they do not wish to conduct research.

While 71% of students with two or fewer years at CU-Boulder planned to go to graduate school in physics, only 40% of students with more than two years at CU-Boulder planned to do so, though this difference is not statistically significant. These younger students made up the bulk of the non-URer population, which may be why non-URers seemed just as likely as URers to want to go to graduate school.

In conclusion, we found that URers started conducting research as early as during their freshman year and only very rarely after their junior year. While non-transfer students were significantly more likely to conduct UR, half of the transfer URers started within their first year at CU-Boulder. Nearly all students plan to continue conducting research, too. While 71% of URers did list experience for graduate school as one motivation for conducting UR, they did not think graduate school is the only reason for doing UR; over two-thirds of URers disagreed with the statement that UR is useful only for people who want to go to graduate school. About two thirds of non-URers shared this view. Very few URers claimed that money and/or expectations to do research contributed to their choice to conduct UR. For students who started their URE after two or three years of study, the most common change they wished to make was to have started conducting UR earlier in their undergraduate career. Over a quarter of URers also said they would
not have made a change to their most recent experience. Most non-URers reported that they wanted to do research sometime in their undergraduate career for the same reasons as URers claimed they conducted UR. Many of these non-URers had not applied for research experiences either on campus or outside of it, however. They often had non-physics-related jobs, either continuing or summer-only. UR did not seem to affect students’ plans to go to graduate school, though time at the school did so insignificantly.

How Faculty Mentors Choose Student Mentees

To speak to students about how they might prepare for a URE, we wanted to determine what faculty look for in a prospective student. In order to do so, we asked faculty members what traits they thought were important for a prospective URer, such as experience in classroom labs and work ethic. We also asked them what characteristics of experiences were common in order to determine what types of experiences were available to students looking for research experiences.

The faculty were offered a Likert scale of five points (later collapsed to a three-point scale as described in the methods) and asked to rate the importance of eight student traits (see Figure XV). Almost all faculty agreed that work ethic, enthusiasm, perseverance, and knowledge of physics were important. It can be difficult to measure those, however, especially during a short interview. These four traits in the context of UR can also be signs of intellectual maturity and curiosity, two traits that researchers embody in their daily work.

A faculty mentor’s history with the student and the student’s previous lab experience were of no particular importance to all of the faculty. However, none of the traits were actually unimportant; for example, while previous lab experience might be a bonus, the lack of it would likely not undermine a student’s application.

We also offered faculty space to write in other traits they considered important. Several of them made comments about programming languages. Computer programming classes are not required for the PHYS students and are for EPEN majors, though many students learn at least one technical language due to the requirements of undergraduate research, their minors, or their
interests. In lab classes, they might also write their reports using a program like Mathematica or MatLab; the university owns licenses to both and offers them to free for students.

![Bar chart](chart.png)

**Figure XV.** Faculty rated the importance of various student traits when considering a prospective URer.

A student’s completed courses was significantly more important to comp/theory researchers than to experimental research faculty (p = 0.03; see Figure XVI(a)). Due to the nature of their research, this valuing of completed courses makes sense. Also, a student’s previous lab experience was significantly more important to experimental research faculty than to comp/theory faculty (p = 0.056). However, that importance was neutral (see Figure XVI(a)) and the distribution was evenly split between the three points (unimportant, neutral, and important). This shows that while experimental researchers may care more about lab experience than do comp/theory researchers, a student lacking such experience would not necessarily be dismissed immediately. Lab skills are most easily taught in a lab and can be easier to teach than some of the concepts from courses that comp/theory faculty claim are very important.

There was another significant difference, this one between junior and senior mentors; junior mentors placed more importance on a student’s previous lab experience than did senior mentors (p = 0.049; see Figure XVI(b)). We checked to see if junior or senior mentors were over-

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* While this is larger than our alpha of 0.05, it is very close and thus we report it as significant.
represented by either research type but the distribution was not significantly skewed in either direction. This difference may be due to the confidence of senior mentors in teaching their mentees lab skills on the job while junior mentors may not have enough experience to know how much they are capable of teaching to the student in terms of lab experience and skills.

![Figure XVI. a)](image)

**Figure XVI.** a) Faculty differed significantly on their opinion of the importance of a student’s course history \((p = 0.03)\) and previous lab experience \((p = 0.056)\). Despite that difference, experimental faculty did not claim that previous lab experience was actually important, merely neutral, with an even distribution between the three points. b) Junior and senior mentors difference significantly in regards to the importance of a student’s previous lab experience \((p = 0.05)\).

In order to determine what type of experiences were common, we asked faculty to indicate the frequency of certain URE characteristics like length or student compensation type (see Figure XVII). There were no significant differences between faculty members by research type or by years of experience mentoring. Most faculty reported that the URers collaborate with the research group on a topic as opposed to developing their own. This makes sense because students may attempt projects too difficult or time-consuming for them, may not know the current status of research in the field, and/or may not understand how their work could fit into the goal of the groups’ project(s). Thus, guidance from the mentor (and possibly the rest of the
research group, including other faculty members, grads/postdocs, and/or other URers) is very important in selecting a topic that is challenging but attainable.

Please indicate which characteristics ... are more common for undergraduates in your group.

![Bar chart]

Figure XVII. Faculty reported what was common for undergraduate research experiences.

Very few faculty reported that short UREs (only one semester) were common. This agrees with data gathered before; most URers, no matter their start year/semester, were continuing their experience. Some reported that they began in 2012 or 2013 yet plan to continue with undergraduate research. While this may include some who took breaks from their research or worked on several projects, it still shows that UREs tend to be longer than a single semester.

Generally, faculty reported that they hired students further into their studies (as juniors or seniors), which conflicts with the data obtained from the students. Only 24% of URers began conducting UR after two years at CU-Boulder and 13% after three years. Over half of URers started within or after their first year of studying, as freshmen/sophmores or as transfers. Half of transfer URers started their experience within their first year at CU-Boulder, but even if they had the credits of a junior or senior, typically transfers are about a year behind non-transfers in terms of classes and/or knowledge of physics. This discrepancy warrants further study, especially for
determining where in a student’s expected course schedule to introduce him or her to UREs and faculty mentors.

Summer and academic year research were reportedly occurring with about the same frequency according to most of the faculty members. This corresponds with previous data; about 30% of students reported that they started in the summer and about 70% started either in the fall or spring semesters. We do not have the data about which semesters they actually conducted research, but since experiences tend to last at least two semesters, students starting in the summer or spring would conduct research during both the summer and academic year; only students starting in the fall (42%) and having a one- or two-semester experience would conduct research solely during the academic year.

Students were paid more often than given course credit for their work, but this skew is not very large; the data was not very sharply peaked and more than a quarter of faculty mentors reported that their students received course credit more often than they were paid. Due to rising costs of tuition, many students work during their college years and so offering money (either from grants or UROP-like programs, for example) may increase the number of students willing to conduct UR compared to only offering course credit. Additionally, some pure physics majors may choose to opt-out of UR in favor of an upper-division lab course.

In conclusion, faculty mentors claimed that a student’s work ethic, perseverance, enthusiasm, and knowledge of physics were the most important traits they looked for in prospective mentees. Comp/theory faculty also agreed that a student’s course history was very important while experimental faculty valued a student’s lab experience more than did comp/theory (though this value was still Neutral rather than Important). Faculty members reported that they most commonly hired URers for longer research projects (2 or more semesters) where the student would collaborate with the research group on a topic rather than developing their own. However, faculty also reported that they hired older students (juniors and seniors) more often than freshman and sophomores; this conflicted with the data gathered from URers, most of whom claimed they started by the end of their third year of studies. Faculty reported that UR was conducted with about the same frequency during the summer as during
the academic year and that students were typically paid, though some faculty members offered course credit more often than paying positions.

How Students Choose UROs to Pursue

We wanted to understand how students choose whether or not to conduct undergraduate research and how they choose from their available options. While the application process is very informal, students still must choose which opportunities to apply for or what professors to seek out. To that end, we asked students how they hear of UROs, what kind of experience they would prefer, the importance of URE characteristics, and how they would agree or disagree with a variety of research-related statements. I present the results from the data and discuss our interpretations of them.

Before students can choose which UROs to pursue, they must hear of these opportunities. We considered what programs students were familiar with in the second section but not how they became aware of them, so we do this now. We asked students to report how they heard about UROs on the campus (see Figure XVIII).

![Figure XVIII](source_url)

Figure XVIII. Students reported how they heard about research opportunities, programs, and groups on CU-Boulder’s campus.
Non-URers were significantly less likely than URers to take an active role in seeking out information about UROs, including talking with other students, discussing research with a professor, discussing research with an advisor, or reading the department’s page. Perhaps students who conduct UR are more likely to talking about UROs because of their close association with professors, especially their mentors and faculty members in their groups, and graduate students. Some faculty members also reported that undergraduate researchers mentored each other in their research group, so URers may talk amongst each other.

Curiously, few students even attended research-related seminars and were of equal proportion when grouped by research experience. Research seminars include such ones as Beyond Boulder and CU Prime. These often offer free food, a draw for college students employed throughout the campus and the city beyond it, though scheduling conflicts may keep many students from attending. URers may decide to not attend these seminars as they are already conducting research and therefore feel the seminars are not relevant to them, may be unaware of them, or may have scheduling conflicts; non-URers may not attend because they are not interested in the presentation or in research, are unaware of them, or have schedule conflicts. Efforts to increase participation in seminars may want to probe more deeply into why students choose to attend or not to attend.

Overall, URers used more methods of gathering information; they had an average of 4.8 of the eleven choices checked compared to 2.5 for non-URers. URers were more likely to engage in all methods of obtaining information about UROs except attending a research seminar. There were no significant differences by major; EPEN majors chose 3.9 methods compare to 3.7 for PHYS majors on average. Even years at CU-Boulder did not seem to affect how many methods students used to obtain information about UROs; they averaged 3.9 choices for students with two or fewer years and 3.6 for students with more than two years.

In order to understand what types of experiences students seek, we asked them to rate their preference for URE characteristics such as length and compensation (see Figure XIX). Students reported, overall, that they prefer longer experiences over shorter. This agrees with what faculty reported was common (longer experiences). Students also appeared to desire to
start research as a freshman or sophomore more than as a junior or senior. Unsurprisingly, they preferred being paid over earning course credit. Due to the cost of tuition and living in or around the campus, even the city of Boulder, most students are required to work and, even then, many of them acquire debt due to their loans for schooling.

Students’ preferences aligned mostly with the common URE characteristics reported by faculty except in one area: students prefer to start early but faculty reported that they typically hired older students. Students reported, however, that they very rarely began their research experience after their third year (only 13% of URers) and were often hired even before finishing their freshman year at CU. The number of students going into UR after two or fewer years at CU-Boulder may be inflated slightly by transfers, but this still shows a discrepancy between faculty perceptions and reported data. This discrepancy warrants further research into exactly when

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**Figure XIX.** Students had preferences for URE characteristics.

Students had no preference for summer or academic year research; the distribution was between preference for one or the other equally, with larger numbers neutral about the timing of the research. The only significant difference for students was between URers and non-URers; the former desired long research experiences significantly more often than did non-URers ($p = 0.02$). This may be because non-URers are more tentative about committing to a long project than URers or because they do not know of any experiences longer than a semester or how long a typical experience takes.

Students’ preferences aligned mostly with the common URE characteristics reported by faculty except in one area: students prefer to start early but faculty reported that they typically hired older students. Students reported, however, that they very rarely began their research experience after their third year (only 13% of URers) and were often hired even before finishing their freshman year at CU. The number of students going into UR after two or fewer years at CU-Boulder may be inflated slightly by transfers, but this still shows a discrepancy between faculty perceptions and reported data. This discrepancy warrants further research into exactly when
students begin conducting UR and what can affect that – for example, due to the declared importance of classes completed, perhaps comp/theory faculty only hire juniors and seniors, but experimental faculty take students from any class, thus skewing the data in favor of older students.

We also asked students how important certain URE characteristics were to them. Most students ranked the start time (as a freshman, sophomore, etc.) as the most important trait. This indicates that most students view when they begin their research experience to be vitally important, though the process of applying and actually getting hired may take some time. Depending on how particular about the type and field of research as well as their faculty mentor(s), students may have to wait for opportunities to open, which could upset the start time of the experience.

Timing (summer vs. academic year research) and compensation (pay or course credit) were ranked by the majority as the least important characteristics. A full quarter of students ranked compensation (pay or course credit) as the least important characteristic of a URE. That compensation would be so unimportant is interesting because students today face huge loans and often work to mitigate what loans they can. However, perhaps students would choose to take course credit in lieu of money because they would be able to fulfill upper-division physics elective credits and, presumably, earn decent grades at the same time without devoting to a “real” course with exams and such. Compensation is also something students can rarely control, as the amount and type is primarily determined by the faculty mentor.

The only significant difference was between URers and non-URers; the former claimed that timing was the least important to them while the latter ranked it the most important, tied with start time (p = 0.002). Perhaps URers have done research during the academic year and during summer and are comfortable with both. Non-URers may also have other commitments (a summer job, for example) that would make timing vital to their choice of URE.

Furthermore, most URers at CU-Boulder assist faculty members with their research projects; we asked students if they knew about such research projects. Non-URers disagreed with that statement while URers were significantly more prone to agreeing with it. The difference was
statistically significant with $p = 0.005$. This kind of research fits most with the apprenticeship model from the literature review, though undergraduates also work closely with graduates and postdocs and may work as apprentices to the apprentices in that case. Faculty research is one way that a university like CU-Boulder can help to support itself and offer interesting experiences to students, so student knowledge of it can be important for recruitment and retention.

In most other respects, however, students with and without research experience agreed on opinions about research activities. Students were likely to agree that their professors were more enthusiastic about physics due to their research, that UR is real research and a vital part of an undergraduate education for all physics students, and that all students within the department should do UR. Thus, to most students, research (both undergraduate and faculty) improves their educational experience and training for future careers. The authenticity of UR (that it is “real research”) is an important part of a URE, according to the literature, so this feeling should be fostered in students. The logistical issues of giving every student valuable UR experiences, which typically do not last only a semester according to the faculty, make answering the last opinion difficult.

However, students with more than two years at CU-Boulder were significantly less likely than students with two or fewer years to agree that UR is a vital part of an undergraduate education ($p = 0.02$). This may explain why these more experienced students were unsure about conducting UR or sure they did not want to do UR in their undergraduate career: because they do not believe it is an important part of their education. That students with two or fewer years believed UR is an important part of their education could also be why none of them said they did not want to do UR sometime in their undergraduate career.

Students similarly held the opinion that UR is not useful only for future researchers or for those who want to go to graduate school and that faculty research does not get in the way of teaching. As discussed before, the belief that UR benefits people besides only those looking for graduate school or future employment experience is an important one for drawing in students who might not otherwise consider UR a valuable part of their education. Thus students see UR
as a valuable aspect of an undergraduate education in physics and only differed in their knowledge of their professors’ research projects.

In conclusion, we found that URers employ more methods and are typically more active in seeking out information about UROs compared to non-URers, but major and years at CU-Boulder did not seem to affect students’ sources of information. Curiously, URers and non-URers were similarly likely to attend a research seminar like Beyond Boulder. Students’ preferences in UREs (such as desiring long experiences over short and having little care as to whether it is summer or academic year research) matched fairly well with what faculty claimed was common except in one area: students preferred to start as freshmen or sophomores but faculty reported that it was more common to hire juniors or seniors. Student data indicated, however, that over half of URers began their experience by the beginning of their second year of study, indicating that there is a discrepancy between faculty perceptions and student reported data. Typically, students claimed that when in their undergraduate career they began conducting research was the most important aspect of a URE, though non-URers claimed that timing (academic year vs. summer) was equally important. Compensation was equally unimportant to both URers and non-URers. URers were significantly more aware of faculty research projects than non-URers, but the two groups were similar in other regards with respect to statements about research. Students tended to believe research benefited them, whether undergraduate research or faculty research, but students with more than two years at CU-Boulder did not necessarily agree that UR is a vital part of an undergraduate education in physics.

Faculty and Student Survey Comments

While we cannot make recommendations at this time, I discuss the comments from the faculty and student surveys. Due to the small number of student participants, these comments should not be construed as general. Though the response rate of faculty members was excellent, their comments are taken somewhat out of context due to the anonymity of the survey.

As one would expect, many faculty comments included some mention of support for undergraduate researchers. The most common type of support was financial; trying to pay a student at full-time during the summer and part-time during the academic year consumes a lot
of funds. This is especially true because URers take a lot of time and effort to mentor and “bring up to speed,” as it were. The second type of support was skills-based; either a course that taught students how to conduct research or supported them in their URE with additional mentoring guidance.

Several comments from the faculty said the department could support their mentoring by providing networking opportunities. A course that prepares students for UR is one possibility; another might be a job fair or web-based forum to which interested students could post a resume, cover letter, and interests. Then faculty members could browser this forum to find potential mentees. This would keep faculty members from being overwhelmed by applicants if they post a job offering, especially by under-qualified students. In the informal system here, typically students must approach faculty about possible UREs; a course would help them build self-efficacy and could help students and faculty connect through something like an informal seminar.

Finally, faculty noted that a local recognition event could improve participation in UR as well as student pride in their achievements. A small poster session, held within the department, could prepare students for bigger poster sessions, provide them with cross-networking opportunities, and encourage social and professional socialization.

Student comments dealt with two main issues: frustration at the lack of networking opportunities and lack of funding. The department’s informal system usually places the burden of approaching a mentor on the student rather than having the mentors seek out students. This can delay the process; as one student said, “even as a freshman, I am interested in research, but I haven’t seen any ways to get introduced to it.” Some wish for more “guidance,” as in a job offerings page just for UROs and/or an up-to-date list of faculty members willing to mentor undergraduate researchers. One student wrote a very long comment about how applying and getting his research position “was one of the most arduous tasks of my entire life” due to how the informal system worked. Faculty noted these issues but wanted the burden of approach to stay on the student, while students wished more of the burden was placed on faculty to make it clear who is and is not looking for URers to mentor.
Also, as one student pointed out, URers “need to eat” and most students pay their own way through school, too. Faculty also worry about funding URers (and about funding their own research). UROP and other grant programs can only provide so much assistance to URers, especially since they are campus-wide programs. Students might accept course credit, but for those who are already fulfilling the department requirements and need the money, UROs that offer course credit would be inaccessible.

Conclusions

In comparing demographic data, we found that there were some discrepancies between our survey sample and the population. The survey showed that non-transfer students were significantly more likely to participate in undergraduate research than were transfer students. Students’ responses to the survey were compared in three dimensions: years at CU, major, and research experience. EPEN majors were overrepresented in the survey data. As expected, URers were also overrepresented in the sample compared to within the department, according to the semester advising sheets. Faculty members’ responses to the survey were compared in two ways: research type and mentoring experience. We used these dimensions to compare the likely responses of each group and determine significant differences between them where appropriate.

For student and faculty awareness, we found that programs, labs, and groups in the Physics Department at CU-Boulder are abundant but not always familiar to faculty and students. Students with research experience were more aware of every program and group we asked about; this was a significant difference for five programs (UROP, NSF REU, the department’s colloquium, CU Prime, and Beyond Boulder). URers were also typically aware of more programs, by number, than non-URers. Those students with more than two years at CU-Boulder were also aware of more programs than those with two or fewer years. For physics research groups in the department, URers were significantly more aware of AMO, Particle/HEP, Condensed Matter, and PER, though all students were mostly unaware of the research groups. Besides campus labs, URers were also more aware of non-campus labs like NIST than non-URers. On the other hand, we found that faculty participated the most in and were most aware of programs that fund undergraduate researchers. They were less aware of groups like CU Prime that offer presentation
opportunities. Thus, we found that student awareness was positively impacted by experience in research and by longer time at CU-Boulder while their participation also increased with research experience. Faculty participated most in programs that help them hire undergraduates (like UROP).

For faculty motivation, we found that most faculty members mentored their own undergraduate researchers, though some did rely on graduate students and/or postdocs in the research group. The average mentor had worked with 1-2 students a year for about twelve years, an impressive accomplishment especially if continued throughout their career. Faculty mentors agreed on four main reasons for mentoring which fell into in two categories: student development and help in the research. There was no clear reason for not currently mentoring, nor was there a single change even most faculty would have made to their most recent experience. In the end, the faculty members make a major commitment when they choose to mentor a URer and have a variety of reasons for doing so.

Turning to students’ motivation, we found that most URers conducted UR to gain experience for graduate school and to learn research skills but typically not to make money or because they were expected to do so. Though less than a third of URers would not have made a change to their most recent URE, none said they would rather not have done research. Most students who started doing UR after two or three years of study reported that they would have started earlier, given the chance. Additionally, most non-URers reported that they did want to do UR sometime in their undergraduate career, and students with two or fewer years at CU-Boulder were much more likely to want to do research than students with more than two years of study at CU-Boulder. Non-URers who did want to do research had the same top two reasons for it as did URers: for graduate school experience and to learn research skills. Over half of all students, with no significant differences between URers and non-URers, wanted to go to graduate school in physics after completing their undergraduate degree. These responses indicated that, for the most part, students chose to or would choose to do UR to gain skills and experience.

When considering faculty selection, we found that faculty members believed that work ethic, enthusiasm, perseverance, and knowledge of physics were very important traits in
prospective URers. Though not specifically listed, several faculty members also commented on computer programming language(s) as being vital to prospective student researchers. None of the eight listed traits were deemed unimportant by the majority of the faculty. An unexpected difference was between senior and junior mentors; the former valued previous lab experience significantly more than did the latter, though neither research type was overrepresented in either group. We also found that faculty offered long UREs lasting at least two semesters more often than short UREs; the URers, who collaborated with the group on a project, more often began the project as a junior or senior as opposed to as a freshman or sophomore. Additionally, students were paid more often than they receive course credit for their work. The frequency of summer and academic year research was the same.

In considering student selection of UROs, we found that students, whether with or without research experience, mostly agreed on what UROs they prefer. In terms of the source of their information, URers used more sources than did non-URers in all cases except attending a research seminar. Students’ preferences for URE characteristics such as length mostly aligned with what faculty reported as common except for in terms of when the student begins; students preferred to start as freshmen or sophomores while faculty reported that they more commonly hired older students, juniors and seniors. Evidence from the students’ responses to a question on their survey, however, would disagree with this claim. In addition, we found that compensation was not the most important characteristic of a URE to most students but start time was. Most students believed that UR was a valuable part of their education at CU-Boulder; URers claimed they knew of their professors’ research projects significantly more often than did non-URers. Students choose UREs carefully as they require extensive commitment from the student, but these results reveal more about how the department and faculty members can support them by providing experiences more closely aligned to their preferences and support them in learning about research.

Future Changes and Lessons Learned

When analyzing the data from the two surveys, we found several changes we wished to make to them, as shown in Table I below. Though we will be unable to re-poll faculty due to the
demands on their time, we can certainly send the student survey out again. These changes fall into three categories: replacements, additional questions, and removals. Replacements typically combine choices or reword choices/questions to improve them so that they are answered (hopefully) more uniformly. Additional questions include those that came about after analyzing the data or finding bits of missing information. Removals were questions that added nothing to the analysis, though this does not mean they were completely useless. We also detail some changes in moving questions around to make a better flow in the survey.

**Table I.** This table summarizes the changes we would make to the student survey before employing it again. The changes are based on analyses of the data and discussions about results and conclusions that came from them.

<table>
<thead>
<tr>
<th>Changes to Student Survey</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove “Never heard of it” and “participated” from familiarity Likert questions and do a more basic familiarity table.</td>
<td>“Participation” in a group is not necessarily equivalent to being “Extremely familiar” with said group.</td>
</tr>
<tr>
<td>Remove question about familiarity with outside labs.</td>
<td>While interesting, this did not provide extensive information to compare. It could be made into a familiarity Likert, but since we wanted to mostly focus on student knowledge of campus and department resources, we think this question could be removed.</td>
</tr>
<tr>
<td>Add question: <em>Have you participated in the following programs and/or groups?</em> (multi-choice: list of programs/groups from familiarity questions)</td>
<td>We want to know what students are/have been participating in so that efforts to increase participation in UR can be targeted for efficiency.</td>
</tr>
<tr>
<td>Move question about preferences for characteristics of UREs to familiarity section.</td>
<td>This is a better conceptual design for students.</td>
</tr>
<tr>
<td>Move question about URer duties to its own block and combine the non-URer and URer versions.</td>
<td>This will enable us to make a more robust comparison since both groups are presented with <em>exactly</em> the same question and possible answers.</td>
</tr>
<tr>
<td>Remove “mentored by” options from duties of URers question.</td>
<td>We want to focus on what students do, not who they are mentored by (we asked faculty that question anyway).</td>
</tr>
<tr>
<td>Add question for URers: <em>How many unique undergraduate research projects have you done?</em> (single-choice: 1, 2, 3, 4, 5+)</td>
<td>We want to know if students are engaged in a single or multiple UREs.</td>
</tr>
<tr>
<td>Add question for URers: <em>How long was your [first, second, third] undergraduate research experience?</em> (single-choice: 1 semester (10-15 weeks), 2 semesters, 1 year, over 1 year) *one per UR project as said above</td>
<td>We want to know how long a “short” experience might be.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Remove URer “where have you done UR” question.</td>
<td>While interesting, the number of URers in any single group is too small to use as anything but a response rate, and we did not even use it for that.</td>
</tr>
<tr>
<td>Remove URer questions about start/end year and end semester.</td>
<td>These turned out to be unhelpful as most students answering the survey were still doing research.</td>
</tr>
<tr>
<td>Add question for URers: <em>Would you recommend doing undergraduate research to your friends and peers in the physics department?</em> (single-choice: yes, no)</td>
<td>We would like to be able to say to students whether or not their peers would recommend UR to them. An optional text box could include a prompt for their reasoning.</td>
</tr>
<tr>
<td>Remove “do you want to do UR” reasons questions for non-URers.</td>
<td>Due to the choices and the smaller number of responses, the reasons for their choice could not be robustly analyzed, especially if they answered “No” or “Maybe.” The question itself, however, remains relevant.</td>
</tr>
<tr>
<td>Add question for non-URers: <em>Why are you not currently conducting undergraduate research?</em> (multi-choice select, use reasons from literature/interviews)</td>
<td>This question was something we wanted to speak to but, due to the way we approached this with “do you want to” reasoning questions instead, it was basically impossible to answer.</td>
</tr>
<tr>
<td>Remove “individual project vs. group project” from bipolar question.</td>
<td>It may be difficult to parse the differences between an individual and group project as most UR projects occur within a research group but with only one URer working directly on the project.</td>
</tr>
<tr>
<td>Remove rankings question.</td>
<td>This is a minor question that did not add much to the final results and conclusions.</td>
</tr>
<tr>
<td>Remove “Astronomy” and “Other” from major choices.</td>
<td>This survey was only sent to PHYS and EPEN majors.</td>
</tr>
<tr>
<td>Replace “how many years have you studied at any college” with <em>Are you a transfer student?</em> (single choice: yes, no)</td>
<td>This will allow us to more easily determine transfer vs. non-transfer, and eliminate errors such as when students did not answer the second question.</td>
</tr>
<tr>
<td>Add question: <em>Have you changed you major since coming to CU-Boulder?</em> (single choice: yes, no)</td>
<td>We want to know if students are “transferring” into the major from undecided/other majors.</td>
</tr>
</tbody>
</table>
If yes, *What was your major before physics?* (text response)

Add question: *Are you considered in-state or out-of-state for this semester?* (single choice: in-state, out-of-state)

Since in-state students pay significantly less in tuition, there may be differences in how many out-of-state students can afford to stay in Boulder for the summer to do research, for example.

**Table II.** We would like to make several changes to the faculty survey even though it will likely not be reused in the department.

<table>
<thead>
<tr>
<th>Changes to Faculty Survey</th>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove “Never heard of it” and “participated” from familiarity Likert questions and do a more basic familiarity table.</td>
<td>“Participation” in a group is not necessarily equivalent to being “Extremely familiar” with said group.</td>
</tr>
<tr>
<td>Add question: <em>Have you participated in the following programs and/or groups?</em> (multi-choice: list of programs/groups from familiarity question)</td>
<td>We want to know what faculty members are/have been participating in so that efforts to increase participation in UR can be targeted for efficiency.</td>
</tr>
<tr>
<td>Remove “individual project vs. group project” from bipolar question.</td>
<td>It may be difficult to parse the differences between an individual and group project as most UR projects occur within a research group but with only one URer working directly on the project constantly.</td>
</tr>
<tr>
<td>Add “knowledge of programming” and “intellectual maturity” to student traits question.</td>
<td>The first was mentioned in several comments; the second was mentioned in post-analysis discussions with faculty members.</td>
</tr>
<tr>
<td>Combine grads and postdocs in “who mentors” question.</td>
<td>Separating them serves no purpose and this helps to shorten the survey.</td>
</tr>
<tr>
<td>Remove “area of research” question.</td>
<td>As with students, inter-group populations are too small to do anything particularly important with.</td>
</tr>
<tr>
<td>Combine Comp/Theory types of research; allow faculty to choose either experimental or comp/theory as their research type.</td>
<td>This will prevent any more mistakes in which faculty chose all three of the research types. It will also allow for easier auto-analyzing using Excel.</td>
</tr>
<tr>
<td>Combine options in “title” question into tenured and not tenured; reword the question appropriately.</td>
<td>The actual title makes little difference and it is tenure vs. non-tenure that we are most interested in.</td>
</tr>
<tr>
<td>Remove gender question</td>
<td>We have no department data to compare this to.</td>
</tr>
</tbody>
</table>
Generalizing the Survey to Other Departments and Institutions

These surveys could be easily generalized or altered for other departments on the CU-Boulder campus and/or for other institutions. Throughout the surveys, the names would need to be altered – the name of the institution and/or departments changed. Programs for the familiarity questions could be changed; for example, while UROP is campus-wide, the BURST program is specific to the biosciences, so if the biology department wished to conduct a survey like this one, they may choose to include it in the list. At other universities, programs like UROP and BURST may exist under different names.

If other universities and/or departments required students to conduct undergraduate research like at Stanford, they may wish to remove the non-URer section entirely and reframe the question about motivation to do research. For example, they could ask what skills the students believed they learned, if they gained confidence in their school work and self-efficacy as scientists, etc. They could also ask the students where they worked and have them review their workplace or their mentor, either in text, with multiple-choice questions, or with agree-disagree Likert scales for statements like “My mentor helped me develop myself as a scientist.”

Future Plans

As for lessons learned, this experience has taught me many things. I have gained confidence in myself as a young scientist and have changed my plans for my future. Now, I hope to take a year to work with the Physics of Everyday Thinking group here in Boulder, led by Dr. Valerie Otero, and then go to graduate school for my PhD in physics education research. The past year has had its triumphs and difficulties, but I am more than content with my experience and cannot wait to continue on the path this has led me.

In the near future, however, I still have many things to complete before this experience is truly over. After my thesis defense, I will prepare a faculty and a student report (and possibly one or two presentations). We also want to make several recommendations to the department in order to improve student and faculty member access to UR. In late July, we are traveling to the AAPT Summer Meeting in College Park, Maryland; there, I will present a contributed talk about this research at my first conference. Then we will stay in Maryland for the Physics Education
Research Conference 2015; I have been invited to talk at a parallel session there, my first invited presentation.

For the next year, I hope to work with Dr. Valerie Otero and the Physics of Everyday Thinking group in order to keep myself immersed in the field. Then I will apply for graduate school and the NSF GRFP; my first choice is to return to CU-Boulder. I would like to continue with this line of research and possibly conduct a longitudinal study of how faculty and undergraduate research affect students, particularly those who do not engage in UR during their undergraduate career.

The authenticity of this project is probably what has affected me the most. I know that I am making a difference (or at least starting one) that will hopefully have a lasting effect on the department. Though at times I grew frustrated and angry at myself or at the data, I would not trade this experience for anything. I cannot wait to see how these results are put to use and what effect they might have.
References

1 Shirley Strum Kenny, Reinventing Undergraduate Education: A Blueprint for America’s Research Universities (2001).


6 Council on Undergraduate Research, (n.d.).


13 H. Lewandowski, (n.d.).


15 M. Healey and A. Jenkins, Developing Undergraduate Research and Inquiry (Higher Education Academy York, 2009).


36 A.W., Astin, Helen S., Higher Education Research Institute (Los Angeles, Calif.), National Science Foundation (U.S.), Astin, Undergraduate Science Education : The Impact of Different College Environments on the Educational Pipeline in the Sciences : Final Report (Higher Education Research Institute, Graduate School of Education, University of California, Los Angeles, [Los Angeles], 1992).
41 Kristen Apodaca, (2015).
Appendix A: Student Survey

Legend
- Indicates a single-selection question (student may only choose one answer)
- Indicates a multi-selection question (student may choose multiple answers)

Bold text indicates sections of the survey visible only to certain students and continues until the next horizontal line
Italic text indicates questions that appear due to a response to the question above them

Undergraduate Research Awareness Student Survey
This survey aims to evaluate student participation in undergraduate research in the Physics Department at CU Boulder. We are studying who is and is not involved in undergraduate research, why and why not, and if there is something the department could do to increase the number of students involved in research.

For this survey, we’re considering any research experience outside the classroom based in science, engineering, technology, or math. If you have had more than one experience, please read the questions carefully to ensure you answer them correctly. You must have had a mentor for the duration of the experience who helped to guide your project. This mentor could have changed and you could have had more than one mentor; mentors include such people as PIs on your research project or graduate students working with you in the lab. You may have earned credit, been paid, or simply volunteered. This experience could have taken place anywhere, on or off campus.

1. Using the given definition, have you done undergraduate research (or are currently involved)?
   - Yes
   - No
2.1. How familiar are you with the following research-related programs and groups on the CU campus? For example, if you have heard of UROP but know nothing about what the group does, choose "Not familiar."

<table>
<thead>
<tr>
<th>Program</th>
<th>Never heard of it</th>
<th>Not familiar</th>
<th>Slightly familiar</th>
<th>Moderately familiar</th>
<th>Very familiar</th>
<th>Participated in it</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Undergraduate Research Opportunities Program (UROP)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>The BOLD Center</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Your Own Undergraduate Research Experience program (YOU'RE@CU)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Discovery Learning Apprenticeship Program</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>NSF Research Experiences for Undergraduates (REU)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Physics Research Opportunities Seminar (PROS)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>CU Prime (CU’)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Beyond Boulder group</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Physics Department Colloquium</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
2.2. How familiar are you with the following physics research groups in the Physics Department at CU? For example, if you know a certain group does research but know nothing about that research, choose "Not familiar."

<table>
<thead>
<tr>
<th>Research Group</th>
<th>Never heard of it</th>
<th>Not familiar</th>
<th>Slightly familiar</th>
<th>Moderately familiar</th>
<th>Very familiar</th>
<th>Extremely familiar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astrophysics and Planetary Sciences (Space)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Atomic, Molecular, and Optical Physics (AMO)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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<tr>
<td>Biophysics</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Chemical Physics</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Condensed Matter</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Geophysics</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>High Energy (Particle)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Nuclear</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Physics Education Research (PER@CU)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Plasma</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

2.3. What labs outside of the Physics Department have you seen advertise that they offer undergraduate research opportunities for physics students?

- National Institute of Standards and Technology (NIST)
- National Oceanic and Atmospheric Administration (NOAA)
- National Renewable Energy Lab (NREL)
- Laboratory for Atmospheric and Space Physics (LASP)
- JILA
- Other universities
- Other private labs
- None of the above
3. How have you heard of undergraduate research opportunities at CU? Check all that apply.

- Talking with other student(s)
- Receiving emails about research opportunities
- Reading the department's research website
- Reading about research online (other than on the department's webpage)
- Discussing research with a professor as part of a class
- Discussing research with a professor outside of class
- Discussing research with my course schedule advisor or faculty mentor
- Reading a poster or flyer posted on a bulletin board
- Attending a research seminar (e.g., Beyond Boulder)
- Through extracurricular groups and activities
- Other ____________________
- I am not aware of any of the above opportunities

For Undergraduate Researchers

4.1. What do you think are the main characteristics of undergraduate research at CU? Please choose 3-6 options.

- Run the main experiment
- Run a side project for the main experiment
- Answer my own questions
- Learn lab/research skills
- Read scientific papers
- Help graduate students with their research
- Bottle washing/soldering; simple, repetitive tasks
- Write a thesis
- Design my own experiment
- Directly mentored by graduate students
- Directly mentored by professor

4.2. How many years had you studied at CU when you started your first research experience?

- Less than one year
- 1
- 2
- 3
- 4 or more

4.3. What semester did you start your most recent research experience? Please choose the option that indicates the semester closest to your start date or the semester in which you had your first day. For example, if you started your experience in August after classes started, please choose "Fall."

Year: ____________
Spring/Summer/Fall: ____________
4.4. Are you still involved in this research experience in Fall 2014?
- Yes
- No

If “No” on the previous question:
What semester did you finish your most recent research experience?
- Year: ___________
- Spring/Summer/Fall: ____________

4.5. Where have you done undergraduate research? You may select more than one if you have had experience(s) at multiple labs.
- Engineering College at CU
- LASP
- NIST
- Other ____________________
- [Options from Question 2.2 that the student did not check “Never heard of it”]

4.6. What are the three most important reasons you chose to do undergraduate research? Pick up to three.
- Research experience for graduate school
- Research experience for employment
- Learn research skills
- Learn about the subject of the research
- Interested in doing research in general
- Interested in doing research in a particular area
- Build a network of peers
- Make money
- Get school credit
- Do something extracurricular
- Felt expected to do research
- Challenge myself
- Other ____________________
4.7. What would you have changed about your most recent experience if you could have? **Pick up to three.**

- [ ] Started earlier in my undergraduate career
- [ ] Waited to start later in my undergraduate career
- [ ] Chosen a longer research experience
- [ ] Chosen a shorter research experience
- [ ] Chosen a different topic
- [ ] Learned more about the research topic first
- [ ] Learned more about the research process first
- [ ] Changed timing from summer to semester
- [ ] Changed timing from semester to summer
- [ ] Changed location to a different lab
- [ ] Taken a class with my mentor first
- [ ] Taken a class about the topic first
- [ ] Had a different mentor
- [ ] Not done research
- [ ] No change

*If “Had a different mentor” is checked:*  
Can you tell us why you would like to have had a different mentor? You do not need to name the mentor or give any specific details.

*If “Not done research” is checked:*  
Can you tell us why you would not have done research? You do not need to give any specific details.

4.8. Optional: Would you have changed anything else?

4.9. Do you plan to continue participating in undergraduate research?

- [ ] Yes
- [ ] No
For Non-Researchers

5.1. What do you think undergraduate researchers do during their experience? Please choose 3-6.

- Run the main experiment
- Run a side project for the main experiment
- Answer their own questions
- Learn lab/research skills
- Read scientific papers
- Help graduate students with their research
- Bottle washing/soldering; simple, repetitive tasks
- Write a thesis
- Design their own experiment
- Get mentoring from graduate students
- Get mentoring from the professor

5.2. Do you want to do undergraduate research sometime during your undergraduate career?

- Yes
- No
- Maybe

If “Yes” is checked:
What are your three most important reasons for doing undergraduate research sometime in your undergraduate career? **Pick up to three reasons.**

- Research experience for graduate school
- Research experience for employment
- Learn research skills
- Learn about the subject of the research
- Interested in doing research in general
- Interested in doing research in a particular area
- Build a network of peers
- Make money
- Get school credit
- Do something extracurricular
- Feel expected to do research
- Challenge myself
- Other ____________________
If “No” is checked:
What are your three most important reasons for not doing undergraduate research? **Pick up to three reasons.**
- No plans for graduate school in science/engineering/math
- No plans for graduate school at all
- No plans for research as a career
- Don’t know what opportunities are available
- Know what opportunities are available, but not interested in them
- Better-paying opportunities available
- Don’t know enough physics
- Don’t know enough about the research process
- Not prepared for doing research
- Not interested in doing research
- Research is boring
- Research is too difficult
- Other ________________

If “Maybe” is checked:
What are your three most important reasons for being undecided about doing undergraduate research? **Pick up to three reasons.**
- Don’t know what opportunities are available
- Need to know more about the research process first
- Need to know more about potential research topics first
- Don’t feel ready for research
- Not interested in research right now
- Don't know how to get involved
- Don't know anyone doing research
- Need more classes first
- Need to get to know potential mentor
- Depends on the topic
- Depends on the mentor
- Other ________________

5.3. Have you ever applied for an undergraduate research position within the CU Physics Department?
- Yes
- No

If “Yes” to above:
Can you tell us a little about that? How did you hear of the experience? Where was it? Who did you apply to? How did you apply to it? What happened after you applied?
5.4. Have you ever applied for an undergraduate research position outside of the CU Physics Department?
- ☐ Yes
- ☐ No

If “Yes” to above:
Can you tell us a little about that? How did you hear of the experience? Where was it? Who did you apply to? How did you apply to it? What happened after you applied?

5.5. What did you do during the summer of 2014? Check all that apply.
- ☐ Summer-only job related to physics
- ☐ Summer-only job not related to physics
- ☐ Continuing job related to physics
- ☐ Continuing job not related to physics
- ☐ Took classes
- ☐ Traveled
- ☐ Other ____________________

For All Students
6. Please rate your preference for an ideal physics undergraduate research experience. For example, if you would strongly prefer a shorter experience (i.e. just one summer), choose "strong preference" on the left.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Short (1 semester)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Summer research</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Start early (freshman or sophomore)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Paid</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Develop own research topic</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Individual project</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Long (2 or more semesters)</td>
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<tr>
<td>Academic year research</td>
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<tr>
<td>Start late (junior/senior)</td>
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<tr>
<td>For course credit</td>
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</tr>
<tr>
<td>Collaborate with professor on a project</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group project</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
7. Rank the following aspects of an undergraduate research experience. Use the drop-down menus to choose 1 as the most important and 6 the least important. You may only assign one number to each aspect.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Most Important (1)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Least Important (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timing (e.g., summer, academic year)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Start time (e.g., freshman, senior)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Compensation (e.g., pay, credits)</td>
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<td></td>
</tr>
<tr>
<td>Origin of research topic (e.g., yours, professor's)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collaboration (e.g., individual or group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Please rate your agreement with the following statements about undergraduate research.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduate research is a vital part of an undergraduate education for all physics students.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>All students in the Physics Department should do undergraduate research.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Undergraduate research is real research.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Undergraduate research is useful only for people who want to go to graduate school.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Undergraduate research is useful only for people who want to be involved in research.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
9. Please rate your agreement with the following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>I know about my professors' research projects.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Faculty research gets in the way of their teaching.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Professors involved in research are more enthusiastic about physics.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

10. Is there anything else you think we should know for the purposes of this survey?

11. What is your major? If you are a double-major, pick the one most closely related to physics.
- ○ Physics
- ○ Engineering Physics
- ○ Astronomy
- ○ Other: ____________________

12. How many years have you studied at CU?
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5 or more

13. How many years have you studied at any college or university (including community college)?
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5 or more
14. What do you plan to do after completing your undergraduate degree?
- Don't know
- Graduate or professional programs in physics
- Graduate or professional programs outside of physics
- Find a job in physics
- Find a job outside of physics
- Take some time off
- Travel

15. Which of the following best represents your gender?
- Male
- Female
- Prefer not to answer

16. Which of the following best represents your racial or ethnic heritage?
- White/Caucasian
- African American
- Hispanic
- Asian
- Native American
- Pacific Islander
- Other
- Prefer not to answer
Appendix B: Faculty Survey

Legend
- Indicates a single-selection question (student may only choose *one* answer)
- Indicates a multi-selection question (student may choose multiple answers)

**Bold text** indicates sections of the survey visible only to certain students and continues until the next horizontal line

**Italic text** indicates questions that appear due to a response to the question above them

Undergraduate Research Awareness Faculty Survey

This survey aims to gather information about faculty participation in mentoring undergraduate researchers in the Physics Department at CU Boulder. We are studying who is and is not involved in mentoring undergraduate researchers, why and why not, and if there is something the department could do to increase the number of students involved in research.

For the purposes of this survey, we’re considering any research experience outside the classroom based in science, engineering, technology, or math as being “undergraduate research.” You must have had an undergraduate student within your research group that you, your postdocs, or your grad students mentored. You could have had more than one student; they may have been CU students or from other universities/schools. This experience could have taken place anywhere, on or off campus.

1. Using the given definition, have you mentored undergraduate researchers?
   - Yes, and I am currently involved
   - Yes, but I am not currently involved
   - No
2. How familiar are you with the following research-related programs and groups on the CU campus?

<table>
<thead>
<tr>
<th>Program</th>
<th>Never heard of it</th>
<th>Not at all familiar</th>
<th>Slightly familiar</th>
<th>Moderately familiar</th>
<th>Very familiar</th>
<th>Participated in it</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Undergraduate Research Opportunities Program (UROP)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The BOLD Center</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Your Own Undergraduate Research Experience program (YOU'RE@CU)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Discovery Learning Apprenticeship Program</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>NSF Research Experiences for Undergraduates (REU)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Beyond Boulder group</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Physics Research Opportunities Seminar (PROS)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>CU Prime (CU')</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Physics Honors Class (PHYS 4610, etc)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Independent Study (research for credit)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
For Non-Mentors
3.1. Why have you not mentored an undergraduate researcher? Pick up to three.
   - Topic is too complicated for undergraduates
   - Undergraduates do not know enough physics
   - Undergraduates do not have good research skills
   - Takes too long to train undergraduates
   - No funding for undergraduates
   - Too expensive to hire undergraduates
   - No room for undergraduates in the group
   - Prefer working with graduate students
   - Prefer working with postdocs
   - Prefer working alone
   - Undergraduates could slow down progress on the project
   - Bad experience with undergraduates in the past
   - Other ____________________

If “Prefer working with graduate students” is checked:
Why do you prefer working with graduate students?

If “Prefer working with postdocs” is checked:
Why do you prefer working with postdocs?

For Mentors (Current and Past)
4.1. How many undergraduate researchers do you typically mentor in one year?
   - 1-2
   - 3-4
   - 5-6
   - 7 or more
   - I do not mentor students regularly

4.2. How many years have you mentored undergraduate researchers?
    Years involved in undergraduate research: _______
4.3. What are the four most important reasons that you mentor undergraduate researchers? Pick up to four.

- Get help with the research
- Add perspectives to research group
- Connect with future scientists
- Offer interesting opportunities to students
- Enjoy watching students grow and develop
- Because I was mentored in my undergraduate career
- Get grant funding
- It is expected of me
- Teach students about a topic
- Teach students about the research process
- Give graduate students/postdocs opportunities to mentor undergraduates
- Other ____________________

For Past Mentors
4.4. Why aren’t you currently involved in undergraduate research? Pick up to five.

- Topic is too complicated for undergraduates
- Undergraduates do not know enough physics
- Undergraduate do not have good research skills
- Takes too long to train undergraduates
- No funding for undergraduates
- Too expensive to hire undergraduates
- No room for undergraduates in the group
- Prefer working with graduate students
- Prefer working with postdocs
- Prefer working alone
- Undergraduates could slow down progress on the project
- Bad experience with undergraduates in the past
- On sabbatical/not doing research
- Not interested in mentoring undergraduate researchers right now
- Other ____________________
**For Mentors (Current and Past)**

4.5. Please indicate which characteristics on the bipolar chart below are more common for undergraduates in your group.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual project</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Student develops own research topic</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Student is paid</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Student starts early (freshman or sophomore)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Summer Research</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
<tr>
<td>Short (1 semester or 1 summer)</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
<td>⬜</td>
</tr>
</tbody>
</table>

- Group Project
- Student collaborates with my group on a topic
- Student gets course credit
- Student starts later (junior or senior)
- Academic year research
- Long (2+ semesters)
4.6. How important are the following traits when you consider choosing which undergraduate researcher to work with?

<table>
<thead>
<tr>
<th>Trait</th>
<th>Not at all Important</th>
<th>Unimportant</th>
<th>Neither Important nor Unimportant</th>
<th>Important</th>
<th>Extremely Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years to completion of degree</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classes completed by student</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student's enthusiasm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student's knowledge of physics</td>
<td></td>
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<tr>
<td>Student's perseverance</td>
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<td></td>
<td></td>
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<tr>
<td>Student's work ethic</td>
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</tr>
<tr>
<td>Previous encounters with student (classroom, etc)</td>
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</tr>
<tr>
<td>Student's GPA</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Student's previous lab experience (Junior lab, etc)</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

4.7. OPTIONAL: Are there any other important traits you consider when choosing an undergraduate researcher?

4.8. Who is primarily responsible for mentoring the undergraduate researcher(s) on your team?

- [ ] Me
- [ ] Other faculty members in the group
- [ ] Graduate students in the group
- [ ] Postdocs in the group
- [ ] Other undergraduate researchers
- [ ] No mentoring
4.9. What would you have changed about your most recent experience of mentoring an undergraduate if you could have? Pick up to three.
- Chosen a student with more years to completion of degree
- Chosen a student with fewer years to completion of degree
- Chosen a longer research experience
- Chosen a shorter research experience
- Chosen a different topic
- Had the student learn more about the research topic first
- Had the student learn more about the research process first
- Changed timing from summer to semester
- Changed timing from semester to summer
- Had a different student
- Not done undergraduate research
- No change

4.10. OPTIONAL: Is there anything else you would have changed about your most recent experience of mentoring an undergraduate if you could have?

If “Had a different student” is checked in 4.9:
Can you tell us why you would have had a different student? You need not include any specific details; we are looking for traits/experiences that distinguish "good" undergraduate researchers from "poor" ones.

If “Not done undergraduate research” is checked in 4.9:
Can you tell us why you would not have done undergraduate research? You need not include any specific details.

4.11. Do you plan to continue mentoring undergraduate researchers?
- Yes
- No

If “No” is checked:
Can you tell us why you do not plan to continue mentoring undergraduate researchers?

---

For Non-Mentors and Past Mentors
5. Is there some way the Physics Department could offer support to enable you to mentor undergraduate researchers?

---

For Current Mentors
6. Is there some way the Physics Department could offer support to enable you to mentor additional undergraduate researchers?
For All Faculty

7. Is there anything else you think we should know for the purposes of this survey?

8. What is your area of research? Check all that apply.
   - Astrophysics and Planetary Sciences (Space)
   - Atomic, Molecular, and Optical Physics (AMO)
   - Biophysics
   - Chemical Physics
   - Condensed Matter
   - Geophysics
   - High Energy (Particle)
   - Nuclear
   - Physics Education Research (PER@CU)
   - Plasma
   - Other: ____________________

9. How would you characterize your research?
   - Experimental
   - Computational
   - Theoretical

10. What is your current title?
    - Assistant Professor
    - Adjoint Professor
    - Associate Professor
    - Full Professor
    - Other

11. Which of the following best represents your gender?
    - Male
    - Female
    - Prefer not to answer
Appendix C: Research-Related Programs, Groups, and Labs

The Undergraduate Research Opportunities Program (UROP)

http://enrichment.colorado.edu/urop/

UROP funds undergraduate research, scholarly and creative work with several types of grants. UROP projects are partnerships between CU’s outstanding faculty and undergraduates from all fields.

The BOLD Center

http://www.colorado.edu/bold/

The BOLD (Broadening Opportunity through Leadership and Diversity) Center is part of CU-Boulder’s commitment to creating an environment where students like you achieve your dreams. Engineering is essential to the health, happiness and safety of our nation and planet, and the strongest engineering solutions are created by a workforce diverse in gender, ethnicity and socioeconomic representation. The BOLD Center fosters success through academic resources, student leadership opportunities and a supportive community in order to break down the barriers that keep too many of today’s young talent from reaching their aspirations.

Your Own Undergraduate Research Experience program (YOU'RE@CU)

http://www.colorado.edu/bold/academics/yourecu-research

YOU'RE @CU is an exciting opportunity for undergraduate students to gain practical research experience in engineering by linking them with graduate students in their majors. Get hands-on experience in your undergraduate years that will inspire you to make a world of difference!

Discovery Learning Apprenticeship Program

http://www.colorado.edu/engineering/activelearning/discovery

Discovery learning allows you to conduct research in an area related to your interests with faculty, graduate students, and industry or government partners. Participating in discovery learning activities is especially encouraged for those students considering advanced degrees or a career in academia.

NSF Research Experiences for Undergraduates (REU)

http://www.nsf.gov/crssprgm/reu/

NSF funds a large number of research opportunities for undergraduate students through its REU Sites program. An REU Site consists of a group of ten or so undergraduates who work in the research programs of the host institution. Each student is associated with a specific research project, where he/she works closely with the faculty and other researchers.

Physics Department Labs

http://phys.colorado.edu/research-overview

Physics Research Opportunities Seminar (PROS)
http://jila.colorado.edu/~ecornell/physics_research_opportunities_s.htm

A lunch seminar that discusses current research on campus that have openings available; only advertised to senior undergraduates and graduate students via email.

CU Prime (CU')
http://www.colorado.edu/studentgroups/cuprime/

CU-Prime (pronounced "See-Yew Prime") is a student-driven effort led by grad students in the Physics Department at the University of Colorado Boulder. Our goal is to increase inclusion in Physics/STEM fields, especially among traditionally underrepresented groups, through mentorship and community building.

Beyond Boulder
http://beyondboulder.pbworks.com/w/page/7904337/FrontPage

Beyond Boulder is a resource for undergrads in fields related to physics and astronomy at CU Boulder. It is a program designed to help guide you through the process of thinking about and planning for your future career.

Physics Department Colloquium
http://phys.colorado.edu/seminars

Independent Study
http://www.colorado.edu/catalog/2015-16/courses/arsc/b-phys/4840-independent-study

Selected topics for undergraduate independent study. Subject matter to be arranged.

PHYS 46x0 (Physics Honors)
http://www.colorado.edu/catalog/courses/arsc/b-phys/4610-physics-honors

Students are matched with a faculty member and work independently on a research topic. Typically, the honors program lasts three semesters. A senior thesis and an oral presentation of the work are required.