Evaluation of the Undergraduate Research Programs of the Biological Science Initiative: Advisors' Perspectives

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Ethnography & Evaluation Research

Center to Advance Research and Teaching in the Social Sciences

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February 2013

Suggested citation:

Hayward, C., Thiry, H. & Laursen, S. (2013). Evaluation of the undergraduate research programs of the Biological Sciences Initiative: Advisors' perspectives. (Report to the BSI). Ethnography & Evaluation Research. Center to Advance Research and Teaching in the Social Sciences, University of Colorado Boulder.

Executive Summary

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This report details the findings from analysis of 31 interviews with undergraduate research advisors who had worked with students in the BSI programs, BURST and UROP. The advisors included graduate students, postdoctoral scientists, and faculty. We highlight some of the most salient findings from the interview data. These include the motivations for research advisors to engage in supervising undergraduates, successful practices for research advising, and student gains achieved through UR (undergraduate research). Advisors reported many increased temporal and financial costs, however, these were outweighed by the benefits both advisors and students gained from participating in research. Intrinsic benefits appeared to be more influential than instrumental benefits, and more experienced advisors commented more frequently on these intrinsic benefits. In their observations of student researchers, advisors also reported many significant student gains in the skills and mindsets of becoming and behaving like scientists.

Due to the advisors' views about the importance of their own experiential learning, we propose that a more research-based training program be developed based upon the successful practices identified in these interviews. A two-pronged training approach might include an initial formal training session for new advisors and ongoing, less-structured discussion groups for advisors of all experience levels. This approach may attract potential advisors to the program and help bolster the skills of those who are already advising undergraduates. In the two sections below, we discuss the findings from these interviews in more depth, as well as the rationale for this revised training program.

Findings from the Interviews

One of the important findings was advisors' different motivations for advising. Each advisor was classified as primarily either instrumentally motivated (5 advisors; benefits for self, such as increased productivity) or intrinsically motivated (23 advisors; benefits for others, such as wanting to help develop the next generation of scientists) based on the main justifications for advising he or she expressed throughout the interview. Early-career advisors were split amongst both intrinsically and instrumentally motivated classifications, while all experienced advisors were classified as intrinsically motivated. This suggests that if early-career advisors do not develop intrinsic motivations, they may not continue advising undergraduate researchers. Some of the reported benefits advisors noted were:

Intrinsic

- improved teaching and mentoring skills
- contributions to preparing future scientists
- deeper understanding of concepts for advisor through teaching undergraduates
- increased energy and enthusiasm in the lab group
- personal rewards (i.e. friendships, feeling of doing something good)

Instrumental

- increased productivity
- career preparation (résumé building and mentoring experience)
- help in recruiting future students
- long-term benefits through students who continue with the same lab for graduate school or careers
- prestige for the university or lab

Interestingly, multiple advisors also reported that students brought into the lab through the BSI programs were more reliable and more likely to finish a research commitment than their volunteer-based peers. This added benefit could motivate advisors to participate in undergraduate research specifically through BSI programs.

In order to develop advising skills, some research advisors (39%) participated in a BSI-sponsored training session. Participants felt that this training session was beneficial, but best suited to new advisors. Indeed, the less experienced advisors reported that the sessions helped them to define their role as a mentor and to set realistic expectations for the students. These skills were identified as particularly difficult to learn by many of the advisors, including the more experienced ones.

Another frequently reported benefit of the training session was being able to converse with other advisors and learn from their experiences. In addition, advisors drew on their own experiences of being mentored as undergraduate and graduate students and on lessons they had learned on the job while advising undergraduates. They highlighted the evolving nature of advising as they felt like they were always learning and adapting.

In fact, many advisors developed strategies to improve the advising relationship from screening candidates in the beginning all the way through publishing and sharing results at the end. Screening procedures helped to identify “serious” students who would make significant contributions to research labs. Some of the more novel approaches included:

- Asking students to write an explanation of why they were interested in working with that particular lab
- Organizing social events where interested undergraduates and potential advisors could connect

- Using the BURST or UROP application process as a litmus test of interest and commitment
- Weighing readiness vs. long-term potential (Less experienced students required more training, but had more years to commit before graduation)

In addition to selecting promising students, advisors were careful to select appropriate projects. They selected projects that provided an authentic research experience, with appropriate levels of challenge and intellectual engagement for the student, so that the experience would be beneficial. At the same time, they were careful to not overwhelm students or leave them to "flounder" by ensuring that the project was intellectually and temporally feasible, and that the student received frequent guidance.

Once research advisors had screened undergraduate candidates and matched them to an appropriate project, they employed specific strategies to systematically introduce lab procedures and expectations to the students, including checklists, handouts (advisors reported using some BSI-provided handouts), and lab tours.

As the advising relationship continued, advisors sought to support students intellectually, personally, and professionally. Advisors worked to understand the needs of their undergraduate students through open communication. They used strategies such as:

- Undergraduate-only research meetings (students were more likely to participate in a group of their peers rather than a full-lab meeting)
- Shared electronic documents to track to-do items and meeting notes
- Pairing students with an easily accessible graduate student mentor for day-to-day assistance (specifically useful for Principal Investigators [PIs])
- Undergraduate journal groups to read and discuss research articles
- Use of electronic messaging to check in with students (Twitter, e-mail, Facebook)

While many advisors relied on these strategies, they stated that the key to a good advising relationship is personalizing the supports to the specific fit between the individual student and mentor. Often, this meant a trial and error process informed by prior experiences of being mentored and mentoring others.

During the undergraduate research experiences, advisors frequently saw students make gains in the areas of *Thinking and working like a scientist* (intellectual gains), *Enhanced career preparation,* and *Becoming a scientist.* To a lesser extent, advisors also reported students had increased *Career clarification*, *Skills* (lab, communication, reading, and scientific writing), and *Personal/professional* growth. These gains are consistent with those students report themselves, although with different levels of emphasis.

Despite careful planning and ongoing communication, some advisors still had reported bad research experiences that didn't work out as hoped. Some of the more severe examples resulted in ended relationships, while mild cases were solved by switching the day-to-day graduate student advisor or by improving communication. Overall, most advisors learned from these experiences and used them to improve their own research advising skills.

Conclusions and Recommendations

Overall, the advisors in this study reported productive relationships with undergraduate students characterized by thoughtful selection, careful planning and orientation, and ongoing support. While this self-selected group of advisors likely represented some of the most successful advisors in the program, these findings are helpful to identify best practices. Additionally, the lessons advisors had learned throughout their undergraduate advising careers could help future advisors to avoid repeating the same problems.

Experienced advisors tended to express more of the intrinsic benefits of undergraduate research experiences, while some of the early-career advisors focused solely on the instrumental benefits of productivity. Advisors noted that, for them, gains in productivity often do not outweigh the costs of training. Taken together, these two findings may indicate a retention problem for advisors who do not see the intrinsic benefits of working with student researchers. Actively advertising the benefits of advising for advisors, their research labs, and students could help to build intrinsic motivation and a stronger sense of purpose in their advising role. Therefore, this may help to encourage new advisors as well as retain current advisors, and could be incorporated into advisor training sessions.

Based upon these interviews, we suggest that the BSI revise and improve current training by implementing a two-pronged program. These could include a more targeted new advisor training session and on-going conversation sessions for all advisors. Those advisors who had attended current BSI training sessions reported that it was most helpful for new mentors in that it helped them to understand the program, their role in the program, and how to set reasonable expectations for undergraduates. Experienced advisors reported that these were some of the most challenging parts when they were new advisors, and were grateful that they were part of the training session. Targeting these areas during the new-advisor training session would be beneficial to help them avoid some of the common pitfalls advisors experienced. For example, seven advisors (23%) made changes to their student screening procedures as a result of poor experiences from misunderstood expectations. Providing new advisors with ideas about screening could help prevent these situations.

In addition to strengthening this new advisor session, an on-going series of themed conversation sessions for advisors throughout the course of the program could help advisors of all experience levels. Advisors stressed the importance of learning from experience, and less formal, conversational sessions would allow them to tap into collective experiential knowledge. These conversations could help advisors to brainstorm together and solve problems while they are actively supervising students. Advisors could also role-play to practice dealing with common situations and concerns that may come up. While these sessions would be most beneficial to new advisors, more seasoned advisors bring the most experiential knowledge and could be encouraged to come as special guests. Many of the experienced advisors in this sample expressed strong beliefs in the value of advancing the scientific pipeline or paying back those who had trained them, which suggests they would likely be willing to help newer advisors as well as undergraduates. Topics might include themes that emerged in this study, identified below. (In addition, we provide some quotations in the report section, 3.5 Bad Experiences that could serve as examples.)

- Selecting students
- Setting appropriate expectations/Introducing a new student to the lab
- What to do when students aren't meeting expectations
- Addressing personal issues in the lab
- Costs and benefits of supervising undergraduate students

As a benefit of participating actively in these training programs, BSI could provide a certificate of completion. Then, newer advisors would benefit not only in building their mentoring skills, but would also gain a valuable credential for future job applications. This would serve as another incentive for participation and would dovetail with current recommendations for improving career preparation at the graduate and postdoctoral stages.

A targeted, rigorous training program based upon these insights from experienced advisors could help new advisors to more quickly build mentoring skills that would normally take years of experience to develop. Additionally, reflecting on why they supervise undergraduate researchers might prepare all advisors to better navigate the tension between productivity and providing the authentic scientific experiences necessary for student gains. This training program could also provide another way for more experienced mentors to contribute to the development of younger colleagues. As a result, research advisors at all levels might be able to better serve the undergraduate students, graduate students, and aspiring faculty in their labs, as well as the greater scientific community.

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1. Overview of the Study

This evaluation study was designed to gather information on research advisors' perspectives on undergraduate research experiences sponsored by the Biological Sciences Initiative (BSI). This study reports on findings from 31 interviews of advisors involved with BSI programs. The study focuses on ways that research advisors supported and mentored undergraduate researchers, as well as the costs, benefits, and motivations of being an undergraduate research advisor. We use the findings to suggest changes to strengthen the BSI advisor training program.

We start by briefly describing the study procedures as well as the demographics of the interview sample. Then, the majority of the report focuses on the findings from the interviews. First, in order to aid in recruitment and retention of research advisors, we explore the motivation for scientists to work with undergraduate researchers and detail the costs and benefits these mentors reported by doing so. Next, we discuss how mentors learned to advise undergraduate students. Since mentors stressed the importance of experiential knowledge, the section after that outlines many of the strategies mentors had developed as they refined their mentoring techniques. These strategies are useful to inform training for new advisors. We also provide some examples of research experiences that did not work out as hoped, and how advisors dealt with them. These examples could be useful in developing content for the training programs we advocate. Additionally, we provide some context for the findings from other literature.

We use the findings from the report to support our recommendation for, and provide content to help create, a two-pronged training approach. This approach includes improvements to the existing new-advisor training, as well as adding ongoing discussion groups for advisors of all levels to learn from each other.

2. Evaluation Design and Methods

This study consisted of minimally structured interviews to encourage interviewees to reveal their own perspectives instead of tailoring their input in response to categories introduced by the researchers. To preserve confidentiality and anonymity, the names of interviewees were known only to the interviewers, and illustrative quotations are edited to ensure anonymity. The study was approved by the Human Research Committee at the University of Colorado Boulder.

Interviews were transcribed and then coded using N'Vivo software. For a detailed description of this process, please see reports of our previous interview studies (Laursen, Hunter, Seymour, Thiry, & Melton, 2010; Thiry & Laursen, 2009). In this study, we have reported frequencies in terms of both the number of participants' observations, or comments, within a category and the number of individuals raising a particular topic. We have generally differentiated these two types of frequencies in the report by referring to the *number of comments* (i.e., counting the number of participants' statements within a particular category) or the *number of advisors* (i.e., counting the number of people who discussed a particular topic).

Because of the nature of semi-structured interviews (as opposed to the uniformity of survey questions), the numbers reported provide a measure of respondents' feedback, but are not statistically tested or generalizable. Questions are not asked in the same order or with the same wording in every interview; and some topics arise spontaneously and thus are not represented in every interview. Moreover, a low frequency does not necessarily reduce the importance of an observation—for example; an explanation given by a single individual may be particularly insightful in explaining and relating observations made by others. Thus, the numbers should not be used to make statistical inferences, but are nonetheless useful to indicate the general magnitude of trends. Additionally, to help draw comparisons, we report some findings as "comments per interview," which is a calculation of the average number of times each theme was mentioned throughout the total interview sample.

2.1. Procedures for Obtaining the Interview Samples

We conducted interviews with research advisors for BURST and UROP students in the fall of 2011 and winter/spring of 2012. For newer advisors, interviews were conducted near the end of the academic year so that they would have at least two semesters of research advising experience to draw on during the interview.

A representative sample of advisors was drawn from lists of BURST and UROP research advisors provided by BSI staff. . We sought to achieve a sample that was relatively balanced as far as discipline, gender and years of teaching experience. E-mail invitations to participate in the interview were sent to 52 research advisors. A follow-up e-mail was sent if the advisor did not respond to the initial invitation. Thirty advisors responded to our request and participated in an individual interview. Additionally, we had invited multiple individuals that worked together in one lab, including graduate students, postdoctoral researchers, and the PI. This group chose to interview together. Therefore, the overall response rate was 60%.

2.2. Descriptions of the Interview Sample[1]

Research advisors worked in a variety of departments. The most common were Integrative Physiology (30% of advisors), Ecology and Evolutionary Biology (20%), and Molecular, Cellular, and Developmental Biology (20%). Other advisors were part of Chemistry and Biochemistry (13%), Psychology and Neuroscience (10%), and Chemical and Biological Engineering (2 advisors). The sample was evenly split at 50% female and 50% male.

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[1] One interview was conducted with a lab group of mixed participants for whom detailed demographic information was not available for every individual. Therefore, descriptions of the sample characterize only the 30 individual interviews.

Most research advisors were graduate students (43%) or faculty members (37%). Postdoctoral researchers (17%) and one technician made up the remainder of the sample. Among these groups, advising experience varied widely, from advisors who were working with their first undergraduate student to some who had mentored "somewhere between 50 and 100" students, in their own estimation, over the course of more than 40 years. We classified those with less than five years of experience advising undergraduates as "early-career" advisors. This included all graduate students and technicians, as well as some of the postdoctoral researchers, and comprised 57% of the sample. All advisors with five or more years of experience advising undergraduates were classified as "experienced." This group accounted for the remaining 43% of the sample and included all faculty members and some of the postdoctoral researchers.

3. Findings

In this section, we report on trends from the interview sample. First, we explore the motivations of undergraduate research advisors in order to aid in recruitment and retention. Then, we discuss how they learned to advise in order to help strengthen training programs for new research advisors. Next, we report on best practices and student outcomes, as identified by these research advisors, to help future advisors maximize the benefits for their undergraduate researchers. Student outcomes are compared to our previous findings from interviews and surveys of BSI students. Finally, we analyze descriptions of 'bad experiences' so that other advisors may use them as learning opportunities. Along with these examples, we discuss some of the strategies advisors have used to remedy these bad situations.

3.1. Why Advisors Take on Undergraduate Students

Bringing an undergraduate student into a research lab is a big commitment that can potentially involve lots of risk. While these advisors did often express a desire to gain an "extra set of hands," that was not always their primary motivation for involving undergraduates in their research. In fact, advisors noted that in the beginning, they sometimes put in more work than what they got back in increased productivity:

> *When you first get them, it's really a burden and it's really stressful because you could be wasting a lot of materials. You could waste time if they end up not being interested. But, for me, they've all been very, very good. …But, at the same time, there are a couple times where they had lost some of the stuff that I had worked very hard on and handed over to them. …That's the only thing that's hard, but you risk that to know that they're going to get better. (Female graduate student advisor, #5)*

Advisors offered a wide range of reasons for why they mentored undergraduates. Given the retrospective nature of the interviews, it was not always clear whether advisors entered into advising relationships aware of all of the reasons they mentioned, or if they had come to realize additional reasons for advising by having engaged in the process.

We classified the different comments about motivations as either “instrumental” or “intrinsic.” Sixteen advisors made 30 comments about instrumental motivations, such as being required to supervise undergraduates by virtue of their position or by their PI. However, 20 advisors made 42 comments about more intrinsic motivations. The most common of these (17 advisors, 30 comments) was that mentoring is an essential element of being a scientist: “Training the undergrads and the grad students is part of my duty. People trained me, so I will do it too” (Male faculty advisor, #14).

While most advisors described a blend of intrinsic and instrumental motivations, we tried to classify each of the 30 interviews based on the main theme expressed. We classified five advisors as “instrumentally motivated” because they made comments *only* about advising being required or a means to increased productivity. Additionally, we classified 23 advisors as “intrinsically motivated.” While they also made comments about increased productivity, they more often described motivations including wanting to help students, enjoying teaching or mentoring, or wanting to “pay back” those who had mentored them. Two research advisors in our sample were not classified because they did not express strong opinions one way or the other. Intrinsically motivated advisors may have been more willing to participate in interviews than instrumentally motivated advisors. So, while this sample includes only a small portion of instrumentally motivated advisors, this distribution may not accurately reflect the motivations of all advisors in the BSI programs.

Table 1. Experience level and advisor motivation.

	Intrinsic	**Instrumental**	**Unassigned**
Early-career	11	5	1
Experienced	12	0	1

Interestingly, all instrumentally motivated advisors were also early-career advisors, as demonstrated in Table 1. There are a few possible reasons for this. First, intrinsically motivated advisors may have been more likely to continue advising throughout their careers, while instrumentally motivated advisors chose not to continue working with undergraduates once they gained the autonomy to make that decision. Our interview data supports this; of the five instrumentally motivated advisors, three started advising as a requirement of their position, one reported that her PI did not explicitly require her to advise undergraduate researchers but did strongly encourage it, and one required help from undergraduates due to the nature of her field work. In addition, six other research advisors, who were also all early-career, mentioned that they, too, had been required to advise undergraduates. However, five of these advisors expressed intrinsic motivations as well. As one advisor said, “It was part of my job, but it was also something I enjoy” (Female technician, #26). (The sixth of this group did not comment on his or her personal motivations to advise, beyond being assigned an undergraduate by the PI, and was therefore unassigned in terms of motivations.) This provides another explanation for the correspondence between early-career scientists and instrumental motivations for advising; it may be that intrinsic motivations became stronger as advisors gained experience and a deeper understanding of the benefits of the advising process, as this speaker suggested:

> *It's closer to home, in terms of mentoring the next generation of scientists. To me, I think it's personally really fulfilling…. It's interesting. This is not something that I felt really strongly about initially, when I was younger. It's something that gradually develops as I age, and now at this stage of my career, I think it's so important to try to keep the pipeline going, and maintain that flow of the young scientists. (Female faculty advisor, #17)*

3.1.1. Costs to advisors.

Despite the many reasons to mentor undergraduate researchers, the time and financial costs were still prohibitive. When deciding to mentor an undergraduate, research advisors considered the effort required to train the student. Advisors were aware that the investment in training might be wasted if students did not fulfill their intended research commitment. Advisors told stories of students who had just stopped showing up, had "personality clashes" with other group members, ate in the lab, or wore clothing inappropriate or unsafe for the lab.[2] From the advisors' perspective, these cases seemed to be rare and mild enough that they were willing to take the risk. Many times, if a student was not working out, advisors remedied the situation by assigning the student to a different mentor (in the case of graduate student mentors) or to another lab that aligned better with his or her personal interests. In order to mitigate risks from the beginning and ensure a good fit, advisors used screening strategies to help pick out the "serious" students from the many e-mail queries they had received, including:

- Collecting transcripts or résumés
- Asking students to write an explanation of why they were interested in working with that particular lab
- Asking for letters of recommendation
- Organizing social events where interested undergraduates and potential advisors could connect
- Using the BURST or UROP application process as a litmus test of interest and commitment

Identifying "serious" students was important to make sure that they would be a valuable addition to the lab. Students needed to commit enough time to positively contribute to the lab, usually around 10 hours per week or more during the academic year. (For a more detailed description, see the section, 3.3.3 Setting expectations and guidelines.) Advisors used the BSI selection process to both assess and build student commitment and interest, as they found that volunteers were much less reliable than students who were participating in the BURST or UROP programs. Advisors speculated that by writing applications for these programs, students felt more ownership of their research project and were more committed. This could be a good selling point for research advisors to engage specifically with BSI-sponsored students.

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[2] For a more in-depth discussion of these experiences, see the section, 3.5 Bad Experiences

As well as weekly time commitments, advisors also considered long-term commitments. Advisors were careful to pick students at the right time in their undergraduate career to balance the knowledge and skills students brought with them against the student's potential to contribute to the lab. In practice, this meant that advisors decided between a younger student who could remain with the lab for a long time but required more initial investment in training, or an older student who was ready to work but sooner lost to graduation. Different advisors had different opinions about how to balance these tradeoffs:

> *Like right now, the kid we have starting on his research project is [in his] junior year and has got more of a background knowledge to pick things up a little bit quicker. (Female postdoctoral advisor, #28)*

> *I like to take on undergrads that are at least sophomores, juniors at the latest. A senior I wouldn't really want to take on, just because it takes a lot of your time to train them and everything, and when they just have a year it's not really good for your time. (Male graduate student advisor, #15)*

Even with these criteria and guidelines, selecting the right student was a challenging process. Different advisors looked for different qualities in potential students, and it was not always clear what kind of student would make a good researcher. As this advisor explained, sometimes, academic records alone were not the best indicator for who ended up being the best researchers, so the selection process was challenging:

> *Some of the best people to come through my lab… they've had a GPA of like 2 or whatever, but that's because they decided that they'd rather snowboard than take classes that they thought were pointless and boring. And yet at the same time they are really good at doing exploratory research. …[To discover them,] interviews are very helpful and then example tasks, whether it's a writing task or whether it's a coding task, can be really helpful…. Having that barrier where they have to be interested enough to [contact] a specific faculty member and understand something about the research going on in that lab – I think that is a really useful first barrier and that helps a lot. (Male faculty advisor, #27)*

In addition to the risk of investing time in a student, advisors sometimes struggled with the financial costs of training students:

> *There's a financial cost that's almost invariable. …To get them to be a little bit more independent, we need to run a training experiment that we wouldn't had to have run otherwise, when we're not really getting new information and new data. We're replicating things that we know how it should turn out to see if they can get it to sort of work in their own hands. And those training experiments can be a thousand dollars each. (Male faculty advisor, #25)*

Advisors incurred other financial costs from broken equipment and wasted reagents, but were quick to point out that scientists at all levels make mistakes, not just undergraduates. Also, advisors felt that allowing students to make mistakes was necessary to ensure an authentic scientific research experience. (We discuss this in more depth in Section 3.3.2

Professional socialization.) While many undergraduates offered a "free" pair of hands to help advance the advisor's research, some did perform independent research projects for senior theses. For this, advisors incurred additional expenses and often had to find ways to support projects from their lab's own funds.

Despite the costs involved, advisors still chose to mentor undergraduates. As one mentor said, "From a business standpoint, [training is] not worth it at all, unless I had some sense that in the long run we'd get some benefit from it" (Male faculty advisor, #25). This suggests that intrinsic motivations may be important, since speaking instrumentally, the costs may be greater than the benefits. The various benefits, both intrinsic and instrumental, are discussed in detail in the next section.

3.1.2. Benefits to advisors.

In this section, we discuss the many benefits advisors saw in supervising undergraduates, both for the students and for themselves. For advisors, the most obvious benefit may be increased productivity through "free" help. Indeed, productivity was the fourth most commonly mentioned benefit. However, advisors also gained other, less tangible benefits from mentoring undergraduates. Advisors reported other benefits including (in order of decreasing frequency of comments):

- improved teaching skills (22 advisors, 49 comments)
- personal rewards such as friendships or a feeling of doing something good (22 advisors, 30 comments)
- career preparation through résumé building and mentoring experience (22 advisors, 29 comments).
- increased productivity (20 advisors, 31 comments)
- deeper understanding of concepts for advisor through teaching undergraduates (16 advisors, 30 comments)
- increased energy and enthusiasm in the lab group (11 advisors, 12 comments)

Some of these benefits may be particularly valuable to newer advisors, especially career preparation. Mentoring experience could be important for young scientists looking for research-based careers, but might also benefit them as classroom instructors:

> *No matter what you do [in academics], you're going to be mentoring somebody or teaching somebody how to do something. So I think just knowing how to do that and how to work with people that do have different ways of learning and internalizing science is very beneficial. And even though it's different than teaching a class, you still get that experience of how to present this piece of information so they understand it. (Female postdoctoral advisor, #28)*

Advisors also noted that undergraduate research benefits the university as a whole by serving as a breeding ground for future scientists (14 advisors), improving the overall prestige of the university (7 advisors), and helping to recruit students (3 advisors). Ten advisors told stories of how students had continued on with graduate school or a job in the same research lab after their undergraduate experience. In these cases, an initial investment in the student had much longer-term payoffs, a selling point which may be particularly useful for advisors concerned with the cost of training undergraduates.

While there were no real differences in the number or distribution of benefit comments, by definition, instrumentally motivated advisors did tend to be more singularly focused on their own benefits, specifically productivity, as in this example:

> *All of them are working on portions of my dissertation, which it clearly is beneficial. Even though it takes time for me to train them in the big scheme of things, [on] large tasks, the hours that they put in are crucial. They save me a lot of time and help with general productivity in the lab. …We get a lot out of having undergrads – if we didn't, then we wouldn't have them. (Male graduate student advisor, #15)*

Intrinsically motivated advisors tended to make more balanced comments about the mutual benefits of advising for themselves and their undergraduate students, and often held multi-faceted views of the benefits. For example, this faculty member explained the two-fold benefits to his graduate students:

> *One is the obvious: [the graduate students] get helped. The other is, it's very easy to forget that you were in that state at one point. I think you learn so much more by teaching than you do even by doing. I think it's really good for the graduate students to be explaining things to the undergraduates and so forth, because they suddenly realize, just like we do when we're teaching, that 'I don't really understand this.' (Male faculty advisor, #10)*

In sum, advisors weighed both the costs and benefits associated with undergraduate research. Those with more experience tended to express more intrinsic benefits of supervising undergraduate researchers. This may be because advisors who focused more on the costs and saw fewer benefits from their initial UR experiences may not have continued to mentor undergraduates throughout their careers. This could be useful for advisor training programs, as advertising the many benefits to advisors could help to encourage new advisors to mentor and to maintain early-career advisors' interest in undergraduate research further into their careers. In addition to training programs, engaging in advising and reflecting on the process may help advisors to gain a deeper understanding and develop intrinsic motivations. In the next section, we discuss how experience played a vital role in learning how to advise undergraduate researchers.

3.2. Learning How to Advise Student Researchers

Although much of their learning about advising student researchers occurred on the job, advisors did not enter into the relationship starting from zero. Some advisors learned about how to advise students through a BSI-sponsored training session. A more common method for many advisors was to model their relationship with research students on the relationships they had had with their own mentors. These two sources of learning how to advise will be discussed individually in this section, 3.2, while the next section, 3.3 Advisor

Support Strategies, discusses on-the-job techniques that advisors used and refined as they worked with undergraduate students.

3.2.1. BSI training.

Twenty of our research advisors commented on the BSI training program. Of those, eight did not attend the training, seven of whom were early-career graduate students or postdoctoral researchers. Moreover, three of those advisors stated that they were not even aware that the BSI offered training. The 12 advisors who did attend the session represented a diverse sample of both early-career and experienced advisors. These attendees reported that the training had helped them to:

- Feel connected to the BSI program, especially knowing what was expected of the students and what resources and training BSI provided for the students
- Determine realistic expectations for students
- Define their role as mentor
- Actively think about mentoring
- Access comparisons and advice from other advisors' experiences
- Problem-solve difficult situations with other mentors
- Gain mentoring resources (booklets and handouts) for use in their labs

These benefits were of particular use to new advisors. Some advisors commented that it would have been more useful to have the session before they even began advising in order to help them start on the right foot. Even holding the session after a few months experience working with students was too late in some advisors' opinions. (Unfortunately, we do not know much about how experienced advisors felt about the training session; of thirteen experienced advisors in our sample, nine did not comment on the training program at all and one did not attend. The three who did comment on attending agreed that the training was best suited to new advisors.)

Four advisors made negative comments about the training program. These advisors felt that the training was not useful because they had learned more from prior experiences, and the training did not provide anything new for them. Overall, many advisors identified prior experience as the best source for learning how to advise, and we discuss this at length in the next section.

3.2.2. Prior experience.

In this section, we explore the role of prior experience, which advisors identified as the best way to learn how to mentor. Advisors reflected on two kinds of experiences: (1) their own experiences of being mentored as undergraduate or graduate students, and (2) mentoring students earlier in their careers. Some advisors worked to avoid qualities of bad mentoring they had received:

> *I would say that I just used my experience having been an undergraduate. …I am always afraid of overworking my undergrads [because] it was really*

overwhelming [for me] while I was trying to complete undergraduate course work. (Female graduate student advisor, #9)

Others described incorporating aspects of good mentoring they had received:

> *I think from, especially one of my advisors when I was an undergraduate, she was really a great role model. Just her excitement and her willingness to help or be available for any questions, and to show hands-on how to do specific things. But also, leaving as much independence as I want and [being] really able to go in what direction I'm really interested in. And then, figuring out as much as I can on my own. (Female graduate student advisor, #7)*

Overall, many research advisors were able to use their own experience and the BSI training session to help them begin supervising undergraduates in productive ways. However, advisors stressed that learning from the experience of supervising students was the best way to improve their skills as advisors. So, in addition to incorporating lessons learned from their mentors, advisors developed many of their own strategies as they worked with undergraduate researchers. These are discussed in the next section, and could be used to develop an evidence-based training curriculum.

3.3. Advisor Support Strategies

In this section, we discuss many of the strategies that advisors used to support their undergraduate researchers. These strategies are categorized according to a structure we developed in prior work in which we interviewed students from the BSI programs (Thiry & Laursen, 2009). Through these student interviews, we identified three main ways that students said their primary advisors supported them, including:

- ***Intellectual support*** *on their research project (e.g. help with problem-solving or identifying the "next steps" of the experiment)*
- ***Professional socialization****, (e.g. transmitting the values and norms of the profession, along with essential disciplinary knowledge and skills)*
- ***Personal/emotional support,*** *(e.g. general comments that advisor is supportive, accessible, friendly, takes an interest in me, etc.)* (Thiry & Laursen, 2009, p. 54).

To these three, we add ***Setting Expectations and Guidelines***, a rare topic when we interviewed students, but much more commonly noted by advisors. In the following sections, we discuss each category in detail and analyze similarities and differences with the types and frequencies of supports reported by students in our earlier study. We also discuss a concern specific to advisors, customizing the supports they offer to meet each student's individual needs.

3.3.1. Comparison to student views.

In the current interviews, the advisors largely reported providing the same types of support as the students had reported receiving in our prior study, as shown in Table 2.

Table 2. Mentor support strategies: Relative frequencies as a percentage of all support-related comments.

Type of Support	Student comments	Advisor comments
Professional Socialization	44%	45%
Setting Expectations and Guidelines	7%	26%
Personal/Emotional	13%	20%
Intellectual	35%	9%

In terms of relative frequencies, advisors were more focused on setting expectations and guidelines while students were more focused on the intellectual support they received from advisors, as shown in Table 2. These differences most likely reflect the more salient issues to each group. In the following sections, we will discuss each of the four support categories separately, in order of decreasing advisor comments.

3.3.2. Professional socialization.

Professional socialization is the cultural and social process through which individuals join a profession. In our previous work on BSI students, we identified four categories of professional socialization that students described their research advisors as providing. In descending order by frequency of student comments, these included disciplinary mooring, teaching new skills, modeling and guiding scientific behavior, and fostering identity development.

Advisors followed this same pattern with disciplinary mooring (30 advisors, 86 comments) the most frequent category. This category included discussing the big picture of science and how their particular project fit into it (33 comments) or providing students with relevant journal articles (30 comments). Advisors also said they taught many new skills (28 advisors, 84 comments). Most frequently reported were lab or data collection techniques (55 comments), but some advisors also taught data analysis skills (16 comments). Advisors said that they frequently modeled scientific behavior (26 advisors, 69 comments), and did so most often by encouraging independence in the lab (54 comments). Fostering identity development (11 advisors, 23 comments) was reported far less frequently than the other categories.

Sometimes, ensuring the professional socialization of undergraduates cost advisors time and money. However, these focus group participants highlighted how mistakes may be costly, but are valuable learning experiences in the development of scientists:

> *Male advisor: [I broke some] custom plasticware... [and the PI said,] 'Stuff breaks.' And I've always had that attitude. …[The lab is] a safe place for people to be creative, which means they're gonna make mistakes. So that's part of the culture, and the expectation is that you're gonna make progress from those mistakes rather than dwell on them.*

> *Female advisor: Yeah. And so long as you learn from them and you don't repeat them.*

Another advisor commented how in addition to losing money, productivity sometimes decreased. However, she felt this was necessary to properly train students:

> *Even sometimes with their help, I can do it by myself five times faster than they can. And you have to be willing to know that they will mess up. …[So] instead of just starting where you want to start, it normally has to be prefaced by the half an hour of going over 'This is what we're doing and this is why it's important.' (Female graduate student advisor, #1)*

Even with the lost time or money, this advisor explained why providing students with authentic research experiences, specifically independence in the lab, was important:

> *It's a safe place to make mistakes. I want you to know what to do and go do it yourself, because you really learn a lot more that way than me kind of answering every one of your questions. Along the way you answer them yourself and figure it out. (Male postdoctoral advisor, #23)*

3.3.3. Setting expectations and guidelines.

In all 31 interviews, advisors raised the topic of expectations a total of 149 times, an average of 4.8 comments per interview. Advisors set expectations and guidelines both prior to students entering the lab and throughout the research advising relationship. The most common example was selecting appropriate projects for students (29 advisors, 68 comments). Some advisors selected projects based on their own research needs while other advisors tried to match students to projects based on the student's interests. Advisors noted the importance of choosing a project that was challenging, yet still feasible. For example, this PI explained how he had learned from mistakes he had seen other research advisors make:

> *Some mentors will give undergraduates massive tasks that involve months and months of work. And so they're giving these students tasks that are far too large in scope, and then not giving them the appropriate amount of supervision during execution of the task. And then the product is usually not adequate because they didn't get enough supervision, or the data simply is not usable, just because the experiment isn't ideal. (Male faculty advisor, #3)*

Advisors also mentioned setting expectations for the students when they first entered the lab (21 advisors, 53 comments). These expectations often centered on lab procedures for safety and maintenance, as well as behavioral expectations such as professional dress and appropriate interactions with research participants. Advisors developed strategies to help systematically set expectations including:

- Checklist to make sure they covered all topics
- Hands-on training for lab-specific procedures and safety

- Handouts for students (some used BSI-provided handouts for this)
- Lab tours to introduce lab procedures, safety equipment, and personnel

While students did not often mention setting expectations and guidelines (only 7% of their support-related comments), advisors mentioned this topic more frequently (26% of their support-related comments). This suggests that advisors were actively thinking about setting expectations while students passively received those expectations as part of the experience of learning new things.

Another common and important theme was setting expectations about time requirements that were non-negotiable. Time requirements were addressed during the screening process, but were also continually set and maintained as students worked in the research lab. Advisors employed strategies to help manage and track these expectations such as frequent, open communication, shared online calendars, and sharing research responsibilities at less preferable times such as early mornings, weekends, and holidays. For example, this advisor's work with live specimens sometimes required working at odd times:

> *The things that we do, …it's kind of like farming more than anything else. So it really involves coming in, being consistently here and sometimes even on the weekends. But if the larvae are ready for dissection on Day Four, and that falls on a Saturday, then you cannot wait until Sunday to do it. We explain it to them, that that's the requirement – that, you know, you cannot follow a five-day work schedule, it just doesn't work. (Female faculty advisor, #21)*

Advisors highlighted how setting expectations from the beginning helped to ensure a successful experience for both the mentor and the student:

> *It's a matter of being extremely clear with what expectations are. I have found that the clearer I am with my kids, the happier we all are. And the more we all get out of it. (Female postdoctoral advisor, #22)*

3.3.4. Personal/emotional supports.

Advisors frequently mentioned supporting students personally through accommodating student schedules and making sure that "classes come first" (mentioned by 71% of advisors). For most advisors, this was not a barrier to working with undergraduates, but it did make scheduling research activities more difficult during the academic year. However, scheduling was less of a concern during summer research experiences, as most students conducted research full time. Advisors managed issues with scheduling by setting clear expectations and openly communicating them:

> *That was the number one thing – 'You're here for school, so we'll be flexible with that. If you have exams and lots of stuff going on, just tell us, and you can get the time off. On the flip side, there are things that you need to be here for. And if we're doing experiments and we need help and you're scheduled, you need to be there.' (Female graduate student advisor, #15)*

While advisors worked to help students balance their personal lives with their responsibilities in the lab, advisors also reported ways in which the two overlapped. Many advisors developed friendly, personal connections with their students, with one advisor even referring to caring for her undergraduates like a "mother hen." Three advisors provided stories of students whose depressive symptoms were interfering with research activities. While this represents only 10% of our advisors, it is not a rare experience: it is estimated that around 40% of undergraduate students have mild to severe depressive symptoms, and the number has been rising over the past decade (American Psychological Association, 2010). Colleges and universities have many programs designed to help students struggling with depression. Since research advisors may have close relationships with students compared to other university staff, they have a unique opportunity to help connect these students with available resources. Making advisors aware of the university resources available to help students would be easy to do, involve only minimal costs, and could help these students gain access to the resources they need. This could be beneficial to the student and mentor both personally and academically, as this example illustrates:

> *And so when he got over to [the health center] and referred to an actual psychiatrist and got help, it completely turned things around for him. So [that is] one problem, especially for students who have a period of high GPAs and then fall off the map, or where it's variable – [but] very frequently, with appropriate accommodation they can wind up being really successful. And making sure that the system doesn't fail them I think is really important. (Male faculty advisor, #18)*

3.3.5. Intellectual supports.

While intellectual support was the least reported of the four types of support (only 9% of support comments), it was nonetheless reported by almost all research advisors (24 advisors, 50 comments). Intellectual supports included answering students' questions about research, discussing student progress and research findings, and assisting students with solving research problems. Advisors made frequent mention of "checking in" with students daily or weekly to gauge progress, discuss findings, and plan the next steps of the project. The relative paucity of comments about intellectual support was likely not because advisors did not view it as important, but because it was considered a matter of course in advising relationships. Advisors most often mentioned intellectual supports when they noted an innovation or improvement in their technique, such as this PI who used Twitter to check in with undergraduate researchers whom his graduate students were directly supervising:

> *I require them to send me a tweet message - not a real tweet, but on Twitter that is the email that may be two or three sentences long - that just updates you on what they've done that week. And I find that very useful. It requires them to really verbalize, and formulate, what they've actually done. They have to put in words what they've actually been doing, and sometimes if you don't ask them to do that, they don't really know what they're doing. And so it helps clarify that, for me. (Male faculty advisor, #3)*

Other advisors used strategies such as:

- Undergraduate-only research meetings, with the rationale that students were more likely to speak up in a group of their peers rather than a full-lab meeting
- Shared electronic documents to track to-do items and meeting notes
- Pairing students with an easily accessible graduate student mentor for day-to-day guidance (specifically useful for PIs)
- Undergraduate journal groups to read and discuss research articles

One piece of advice that advisors offered to the BSI program was that advisors and students alike could benefit if advisors were more aware of the requirements for students in the BSI programs. Advisors would then be better prepared to proactively support students in preparing their papers and presentations, as students sometimes waited until shortly before the deadlines to ask for assistance.

3.3.6. Customization of supports.

Our previous work (Laursen et al., 2010) detailed the importance of students' engagement in authentic science to maximize gains from undergraduate research experiences. The quality of advisor support for authentic science experiences is crucial, and for the most part, our advisors related deep understanding of the importance of these supports, as well as strong implementation, as this mentor explained:

> *I've seen people go all the way through graduate school and not really understand experimental design because they worked on a major professor's grant and it was all designed. They just did the work, published it, counted it as their thesis, and they really didn't have a good understanding of how to do science. …We've had very few students who actually start a project that don't finish it. Because they get to work on it, they get the whole picture of how science is done. (Male faculty advisor, #10)*

Some advisors did report struggling with some aspects, especially knowing what expectations were appropriate for undergraduates. Other advisors outlined the growth they had experienced as mentors through the struggles they had had earlier in their careers. Advisors offered many solutions, and some stressed the individual nature of advising: there are no across-the-board solutions that will work for every student. This advisor told of explaining this to her graduate students who served as mentors:

> *How to work with each student, how to help each student realize their potential, how to work with them so that they can realize their potential. I tell them all the time that it's difficult to figure out what's the best way to work with each student, and each student is different. (Female faculty advisor, #8)*

She went on to note that, nonetheless, sometimes advising relationships just don't work because of "personality clashes":

> *Some mentors just want to tell them what to do, and you have to make sure that that is matched with the undergrad's willingness to do that. Whereas some undergrads really want to feel like they can – not mess around, but check things out for themselves a bit more. I want to give them the freedom. … Some grad students don't really have the patience for that, they just want it to get done. So, it's making sure that that's a good fit, I think, helps. And if it's not, I try to shift it so that it could be a good fit. (Female faculty advisor, #8)*

In total, these advisors reported using many support strategies to engage students in authentic scientific research experiences. The importance of this is highlighted again in the next section, where we discuss what students gained from participating in these authentic undergraduate research experiences.

3.4. Student Outcomes

Overall, advisors and students in the BSI programs identified similar gains for students from participating in undergraduate research, as shown in Table 3. Student interviews were conducted 4-5 years before the advisor interviews and do not necessarily represent matched pairs of undergraduates and their advisors. However, given that many BSI students participate in research during more than one year (Hayward, Kogan, & Thiry, 2012) and roughly half of the advisors in this sample had five or more years of experience, some advisors had likely mentored some of the students in the original interview sample.

Table 3. Student gains: Average observations by gain type, per interview.

Category	**BSI Advisors** (n=31)		**BSI Students** (n=33)[3]	
	Positive Gains	Negative/ Mixed Gains	Positive Gains	Negative/ Mixed Gains
Thinking and working like a scientist, Intellectual gains	4.81	0.32	6.52	0.52
Enhanced career preparation	4.19	0.03	1.39	0.00
Becoming a scientist	4.10	0.13	5.03	0.24
Skills	2.10	0.00	4.36	0.39
Career clarification	1.97	0.03	3.18	0.24
Personal/ professional	1.64	0.06	3.27	0.18

[3] Positive and negative gains for students are from Thiry and Laursen (2009).

Table 3 is the most useful in comparing the relative frequency of gains-related comments within each group, but readers should not directly compare these frequencies across groups. For example, the numbers imply that students made more comments per interview than advisors, but this is likely due to differences in the interview protocol and in the resulting coding scheme. Advisor interviews focused on a wider range of topics, whereas student interviews focused more intensively on outcomes and were coded with a higher degree of detail.

Among both advisors and students, the most commonly reported student gains were in *Thinking and working like a scientist,* or intellectual gains, such as critical thinking, problem solving skills, data analysis, and experimental design. Relatively, advisors commented more on *Enhanced career preparation* than students did, likely due to the benefit of hindsight. Advisors have seen where undergraduate research experiences have led others, while students participating in research don't often know where their future will lead or how the experience will benefit them. Advisors focused relatively less on *Skills* that students had developed, such as lab skills, communication skills, and scientific reading skills. This may be because, for advisors, skill gains are expected and more obvious outcomes of research experiences. Advisors may again benefit from hindsight in seeing how the less-tangible gains have higher long-term importance, and therefore do not comment as often on these tangible *Skills*, which are important and novel to students.

3.4.1. Outcomes based on advisor characteristics.

Overall, both intrinsically and instrumentally motivated advisors focused most on the identity and intellectual gains of becoming and behaving like scientists. While all advisors provided evidence that students made gains through research, on average, intrinsically motivated advisors made more comments about gains (19.4 comments per interview) than instrumentally motivated advisors did (16.0 comments per interview). These trends held across most categories as well, as shown in Table 4 below.

Table 4. Student gains observations by advisors, per interview.

Category	Intrinsically Motivated	Instrumentally Motivated
Thinking and working like a scientist, Intellectual gains	5.4	4.2
Enhanced career preparation	4.3	3.6
Becoming a scientist	3.8	3.6
Skills	2.1	1.0
Career clarification	2.0	2.4
Personal/ professional	1.7	1.2

Interestingly, the trend did not hold for *Career clarification* comments, as instrumentally motivated mentors made just slightly more comments on average. Given the slight difference in the numbers and low sample sizes, these differences are probably not significant. However, of the four instrumentally motivated advisors (out of five total) who commented on *Career clarification*, two of those advisors compared their mentee's experience to their own experience deciding which career path to follow. These advisors were both early in their careers and therefore closer to having made career decisions themselves. This may suggest that early-career mentors have not developed a broad understanding of advising beyond their own experience, as this quote from an instrumentally motivated graduate student exemplified:

> *I've worked with one other undergraduate, who is now also a master's student. She had the same experience I did. She loved it and decided to stay for the master's. …[My current student is] still interested in going to med school, but she would do that after the master's. The two undergraduates I worked with during my master's work, they've gone on to med school, they're both in med school now. So, I didn't sway them (Female graduate student advisor, #9)*

In this quotation, the advisor did not see the benefit of undergraduate research opportunities as a space for exploration and career clarification amongst a variety of possible paths. Rather, undergraduate research experience was described almost as a one-way ticket to graduate school in the research sciences. A second early-career, instrumentally motivated advisor explained the self-propagating nature of this mindset:

> *We all drink the Kool-Aid, and we pass that on. There is always the self-recruitment for academic types, once you're in that setting. But I think all these people also knew that doing just chemistry, or biology, with just a bachelor's degree doesn't get you far. …I'd say it's probably a low reinforcement from the mentality inside the lab to keep going to school, and to keep bettering yourself. (Male graduate student advisor, #4)*

Viewing undergraduate research opportunities as simply a means to get into a good graduate program may overly focus advisors on equipping students with technical skills. It may also lead them to ignore many of the transferable benefits such as critical thinking, data interpretation, and communication skills that are essential to many professions. For example, one research advisor explained:

> *I don't encourage students to do an honor's thesis at CU. It doesn't help them get into grad school. …If they finish it when they're a senior, it's not on their transcript when they're applying for grad school. (Male postdoctoral advisor, #23).*

Such advice might cause students to miss out on the many higher-level developmental opportunities afforded through ownership of an independent research project. To be fair, this particular advisor did encourage students to participate in other higher-level scientific activities:

> *UROP, and publications, and presentations at meetings is [on their transcript when they're applying]. …[For one student] it wasn't until a year after he graduated that he was accepted to graduate school. He had some other issues on his transcript, but Honors didn't just fix it. It was his co-authorship on publications, and the experience that he had with me. (Male postdoctoral advisor, #23)*

If advisors take a narrow, instrumental view of the benefits of UR focused on graduate school, they run the risk of not offering the authentic learning experiences that foster deep, transferable skills in students, or of pushing students down a path that is not the one the students truly want to follow. Therefore, it's useful for advisors to understand the benefits to students that have been well documented in recent research. (Laursen et al. (2010) provide a review of this literature in Chapter 2 of their book, *Undergraduate Research in the Sciences: Engaging Students in Real Science.*) In the next section, we provide some examples of bad advising experiences that had been particularly useful in helping advisors improve.

3.5. Bad Experiences

While most advisors described positive research experiences, some did not work out how the advisors had hoped. In this section, we analyze these experiences in order to share some of the ways advisors handled these situations, as well as the lessons they learned in order to have more successful undergraduate research experiences in the future.

Reports of bad research experiences were infrequent and most were mild. In our sample, 22 advisors shared 29 examples of bad experiences. Of these, seven examples were stories that advisors had heard about another advisor's experience, rather than their own, and not all of these stories were about BSI students. Seven advisors explicitly described examples of a lack of commitment and motivation from volunteers in their labs, rather than from students funded by BSI programs. However, the lessons learned from these experiences may still be informative for BSI advisors and students. Additionally, advisors believed that pre-med students were less reliable due to being overly burdened with commitments or a desire to do research "just to get it on their résumé."

Advisors shared stories of bad experiences in a few different categories including:

- Students lacking motivation or commitment (17 advisors)
- Poor mentoring from graduate students (11 advisors)
- Not enough effort or time from students (9 advisors)
- Students' personal problems or lack of maturity (9 advisors)
- Advisors not providing 'real science' (2 advisors)
- Advisor giving an overly challenging project (1 advisor)

The experiences are grouped according to the severity and eventual outcomes. We also describe some of the ways that advisors have responded to these situations. We provide the quotations in their entirety so that excerpts may be used for training purposes.

3.5.1. Severe Examples – Ending the Advising Relationship.

Advisors were able to remedy most situations. Only five examples reached the point where student behaviors were so egregious that advisors had to end the relationship with the undergraduate researcher. Some of these more severe examples included:

> *[One student] was just basically cheating on the time sheet… just putting down times when they're not here … It was so blatant, and they included times that the student was actually in a class I was teaching. …It turned out that this student had done the same thing with two other PIs. (Female faculty advisor, #21)*

> *I felt like I reached out quite a bit to this young kid, and he was going through some personal issues at the time. I think he got himself into some trouble with police. He was lying to me why he wasn't coming to work, and I was just trying to get the best out of him and do what I could for him because I knew that this was probably a difficult time for him. He ended up leaving our group and telling the staff that the reason he was leaving our group was the lack of access to the facilities of the lab group, which was not true. That was personally really upsetting to me. (Male postdoctoral advisor, #18)*

3.5.2. Severe Examples – Improvements to Future Screening Procedures.

While severe examples are rare, they do shed light on the importance of good mentoring practices, especially strategies mentors can use to prevent problems in the first place. Advisors mentioned making changes to their screening and selection procedures in order to choose more promising students (7 advisors). One advisor recounted a story of how the lab had, against their better judgment, bypassed its normal screening procedures to bring in an undergraduate researcher's friend, but learned from the mistake:

> *[All the other students] went out and did active research on the websites for who does what and they just really genuinely wanted to work there. …[We had problems with one undergraduate who didn't come in] through any particular program. It was actually a friend of one of the undergraduates … that we already had, being like 'I know this person, it should be fine.' The advisor was kind of like 'I don't really know, because they didn't approach me directly.' They went about it anyway, and we ended up falling apart because they didn't realize, they didn't have the respect for what we were trying to do. …[Now], we have a process in our lab where if someone wants to join the lab, graduate student, postdoc, it doesn't matter, undergraduate, that everyone has to sit and talk and give their feedback at the end. 'Would the chemistry work?', and that kind of stuff. And that all came about after that one undergraduate had caused some problems. (Female graduate student advisor, #5)*

Another advisor told a story about how she was not aware of a student's aversion to necropsying frogs until the student actually had to do the procedures. This led to the undergraduate switching out of the lab, and subsequently, changes to the lab's student screening procedures:

> *One thing I'm learning is in this type of research it's really important to discuss with people ahead of time – you're going to have to euthanize frogs, and we do it humanely, but it's part of our research and you have to be comfortable with it. …[Now] they start off with a tour of the facilities we have. We have animal control, temperature control rooms. We'll show them the different species that we work with. Usually you can tell at that point if they're like 'This is cool', or 'Eww, that's gross.' Then you start to decide maybe you're more meant to do some more microscope work and less with the animals. Or you really enjoy working with the animals, but then you get attached to them, and maybe not doing so much of the necropsy work. I find that getting them hands-on in the lab, you can tell a lot about the students based on their reactions. (Female graduate student advisor, #16)*

3.5.3. Moderate Examples – Switching Advisor/Student Pairings.

Not all problems were fixed only retroactively. Ten research advisors had been able to solve problems "on the fly" with their current students. Four advisors switched the student to a different day-to-day mentor or another lab group in order to have a better fit with personalities or research interests. This PI explained how this worked when his graduate students were paired with undergraduate researchers:

> *It's very highly dependent on both the immediate supervisor and the undergraduate. You take a flying chance and hope that the one you gave them is one that will work out. But, it isn't always, and sometimes you have to change projects. …I don't give them the boot. I try to help them get as much out of it as they possibly can while they're here. (Male faculty advisor, #11)*

3.5.4. Moderate Examples – Maintaining but Changing the Relationship.

Rather than moving the student out of the lab, most research advisors used different communication strategies to address issues as they arose (9 advisors), while maintaining the relationship. This PI explained what he does to improve relationships between his undergraduate students and their graduate student mentors:

> *You talk to the immediate supervisor and say, 'Let's see what we can make of this.' They will then work with them in maybe a different way, or more hands-on way. They won't take over the project, though. I've never had a grad student or postdoc take over the project of an undergrad. (Male faculty advisor, #11)*

Some advisors also used more formal strategies, such as this advisor:

> *Sometimes when working with older adults [as research participants], I would prefer to have an added level of maturity that I don't always get with an undergraduate. I had one guy, I would say the closest we ever had to having a problem, was he'd come in hung over for some of our visits. It can be a problem. …In the lab that I just joined, they actually have a new employee handout that they give the undergraduates. That actually gives them a dress code and a conversation code. That's actually something that I am going to carry on when I go further, because unfortunately not a lot of students know that right away. (Female graduate student advisor, #9)*

Another advisor used technology to assist her:

> *I think a lot of it is communication. I think that, you know, with my group meetings, I always like to open the floor to, "What are you guys thinking? What are you doing? Where are you at?." And I remember... it's been a few years now, but I had one student say, "Why don't we all join Facebook and we'll come up with a group blah blah." Which isn't great for what we do, because we don't want the rest of the world knowing exactly what we do. But that always kind of ran around in my head, and when I finally learned Google Calendars, I was like "Ah ha! This is what we need." …But it's communication. I learn more from my kids when I work with them side by side, or in our emails, or in our meetings. More where they're at, which, you know, gets me thinking more of like what we can kind of do together to make the science move along more steadily. (Female postdoctoral advisor, #22)*

3.5.5. Mild Examples – Increasing Motivation.

Advisors also told about the difficulty of unreliable volunteers. While this is not necessarily a BSI-related problem, at least one BSI student did become less committed as the funding ran out. Advisors offered a number of ways to motivate students in this situation:

> *I would routinely in the past few years offer to pay them hourly [from my own funds]. That would kind of motivate them. Just a tiny little hourly salary can make all the difference on the level of reliability. (Male faculty advisor, #14)*

> *And you know, when the money starts to run out you can kind of tell. …We do our best to fund everyone in some way, even if we're just paying them gas money. …We try to like take them out to dinner and do other things to show them how much we appreciate their time. (Female graduate student advisor, #30)*

3.5.6. Personal Life Spillover – Helping Students Get Help.

A handful of advisors mentioned personal problems that spilled over into the lab relationship. For example, advisors mentioned different ways of dealing with students' depressive symptoms:

> *I think he suffers from depression. He's alluded to some issues. He's been my challenge, because he has all the potential in the world, but he really falls off the radar, and at times I just can't get in touch with him. And I would worry, and call, and ask his friends, and then I decided to let him know, 'You are responsible for letting me know what's going on, and I'm not going to chase after you. And if something is going on that is relevant to you not getting work done that is my business. Because if you don't show up, I do worry. Otherwise you don't need to tell me the details.' (Female faculty advisor, #6)*

> *The resources at CU for dealing with mental illness are very good. However, in general the students do not seem to be aware of them. And especially for things like depression, which are very prevalent in academic populations, they're not really talked about. There are a lot of great resources that either people in my lab or contacts through the Honors program have been able to put them in touch with – and wider recognition would probably be useful. (Male faculty advisor, #27)*

In spite of the difficulties some of these advisors faced when supervising undergraduate researchers, most of them were able to use these situations as learning experiences and improved their own research advising skills as a result. In the next section, we look at the results as a whole and place them in context of other work on undergraduate research advising.

4. Context for the Findings

Key findings from this study address research advisors' motivations to carry out UR, the costs and benefits to advisors from participating, as well as their observations of student outcomes from UR. Several of these topics have been addressed in prior studies by E&ER and others, yet overall our understanding of advisors' work lags well behind our understanding of what and how students gain from carrying out undergraduate research. Better understanding of how UR operates from the research advisors' perspective can help to illuminate the teaching and learning processes that take place in the research lab, enabling organizations such as the BSI to better select and support advisors in their work with undergraduates. It is also important to understand what advisors gain (or fail to gain) from a one-on-one research mentoring experience, so that advisors can be effectively recruited and well prepared for their experience. Here we place key findings from this study in the context of this prior work.

Our findings from this study about the costs and benefits to advisors are generally comparable to those reported in E&ER's four-college study (Laursen et al., 2010) and by

Dolan and Johnson (2009) in their study of graduate students as research mentors. These studies concur that, in general, benefits to advisors substantially outweigh the reported costs. Instrumental concerns about productivity weighed more heavily against intrinsic and personal gains for some individuals than for others (Dolan & Johnson, 2009), but they are a fundamental element of the tension between the dual functions of undergraduate research as an educational experience for students and a scholarly activity for faculty (Laursen et al., 2010; Laursen, Seymour & Hunter, 2012). Dolan and Johnson (2009) find that graduate students' initial motives were immediate and narrow, yet their reports of gains and challenges indicate a broader vision of how mentoring may be beneficial to their personal and professional growth. Our findings suggest a similar evolution from instrumental to intrinsic views for many advisors as they gain experience and come to appreciate the outcomes for themselves and their students and to savor the interesting challenges of mentoring diverse students.

Advisors' descriptions of the procedures they used to select and support student researchers are comparable to those observed in other studies. Laursen et al. (2010) sort advisors' selection criteria into two main types, evidence of student academic achievement, and evidence of student interest and curiosity. While advisors reported paying significant attention to student selection, they also noted that, even after years of experience, their selection methods were approximate at best: sometimes academically strong students did not perform well in research settings, but other times advisors discovered a "diamond in the rough" in a student whose research aptitude had not initially been apparent. Laursen and coauthors also provide detailed examples of advisor strategies for teaching through authentic problems encountered in the laboratory, which may be helpful to research advisors in establishing and refining their own working methods.

Advisors' observations of student outcomes generally mirror both BSI student reports and reports by research advisors in the four-college study and other published reports (Laursen et al., 2010). One interesting difference is undoubtedly related to the context for the studies. In the present study, university-based advisors placed more emphasis on career-related outcomes than did the liberal arts college faculty in the four-college study. This may be due both to real differences in the impact of the environment on students (e.g. working with large research groups with scientists at multiple career stages vs. in undergraduate-focused labs) and to advisors' perceptions of the importance of research exposure for scientific careers or for a broader range of careers.

Analyses of larger-scale data sets by Eagan et al. (2011) and Lambert et al. (2009) identify some personal and institutional characteristics that are associated with UR opportunities for students. For example, Lambert and coauthors (2009) find that male faculty spend more time on undergraduate research than female faculty, after controlling for institutional differences. Eagan et al. (2011) find that faculty at historically Black institutions and liberal arts colleges are more likely to involve undergraduates in research. Both papers argue for the importance of institutional reward and support structures to enhance UR opportunities. As we have argued (Laursen, Seymour & Hunter, 2012), undergraduate research is a powerful educational experience for students, yet one that demands high commitment and skill from research advisors who work with them. We argue that it can only be helpful to advisors to make explicit the inherent tensions built into the very structure of UR and to help them decide how best to navigate those tensions in their own work with students.

5. Conclusions and Recommendations

For these advisors, hosting undergraduates in the lab, while potentially beneficial for productivity, was risky and required large investments of time and, in some cases, money. Many research advisors cited more intrinsic motivations for advising, including "maintaining the pipeline." Advisors also wanted to "pay it forward" in the same way as the mentors that had shaped their own career decisions. These more intrinsic motivations may develop over time as the advisors continue to supervise undergraduates and reflect on the process. Overwhelmingly, advisors had learned to mentor by example and experience. They reported many useful strategies and techniques, some of which they had borrowed from their own mentors, and others they had developed through their own experiences. Advisors also reported that students achieved many important gains through engaging in authentic scientific research, most notably the skills and mindsets to be successful scientists in future careers.

These findings are useful to help other research advisors learn from the experiences of this group of advisors and gain skills more quickly than their own individual experiences would provide. The BSI could use these lessons to improve advisor training programs. Given the different views expressed by early-career and more experienced advisors, as well as the importance they all place on learning from experience, we suggest that the BSI adopt a two-layered approach for advisor training. This two-layered approach might include an improved session for new advisors and an ongoing topic-based discussion groups for advisors of all levels.

Since advisors felt the current training was most useful for new advisors, this training could be continued, but targeted more specifically to the concerns of new advisors. For example, it could focus on issues that early-career advisors struggled with, such as selecting appropriate students and projects, setting realistic expectations, maintaining clear communication with students, or understanding the BSI program requirements. This training could be useful if conducted before advisors even begin working with undergraduate students, as some advisors mentioned that they would have liked to have known these things before starting.

Additionally, presenting the benefits of advising for students and their advisors would be especially useful for new advisors to understand their role as mentors. This may also encourage their retention as research mentors, as more experienced advisors tended to express more intrinsic motivations and to observe more student gains. Given that seven of the eight advisors who said they had not attended the BSI training were early-career, we believe it would be beneficial to require new advisors to attend this training program. Receiving a certificate for completing undergraduate research advising training could be helpful to these advisors when they seek new employment or tenure.

Since it is not possible to cover every situation in a pre-advising training session for new advisors, it could be supplemented with on-going conversation between advisors of all levels. This could help new advisors, as well as more experienced advisors, tap into their collective experiential knowledge. Then, advisors could continually develop their skills and solve problems in real time as they are working with undergraduates. Reflecting with other advisors may help to develop a deeper understanding of undergraduate research advising, especially the intrinsic motivations that could lead to greater advisor retention. To increase participation of more experienced advisors who bring with them more knowledge and skill, they could be invited as special guests or to participate as part of an "expert" panel. Again, advisors could be provided with a certificate for active participation in these sessions, which would be especially useful for early-career faculty and for those planning to pursue faculty careers.

These conversation sessions could be framed around some of the challenges that advisors identified in this study, such as selecting promising students, setting and maintaining expectations, or dealing with challenging situations. Conversations could also discuss the costs and benefits for both advisors and students, which could help advisors develop more intrinsic motivations. Also, reflecting on student outcomes may help advisors to more effectively balance the need for productivity with providing students with authentic scientific experiences.

One additional, less time-intensive option could be to encourage research labs to have these conversations on their own. BSI may want to encourage and support labs to undertake conversations around the questions "Why do we have undergraduates in our lab?" or "What's in it for us? What's in it for the students?." Labs could also be encouraged to talk about concerns they have or potential problems they foresee in order to help develop their own strategies. If our focus group is any indication of the dynamic of other labs, posing these broad questions could lead to rich discussions in which many of the findings discussed in this study would likely emerge.

Improving the advising skills of undergraduate research advisors would immediately benefit undergraduate students, and may have long-term career benefits for both the advisors and the students.

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Undergraduate Research Advisor Interview Protocol

<u>Interview questions</u>

Thank you for participating. The goal of the study is to understand better what goes on in students' undergraduate research experiences and how advisors work with undergraduates. We also want to help the [program] to improve these opportunities for students and improve their support of students' research advisors.

Your participation in this study is voluntary. You may refuse to answer any question at any time. Your responses are confidential. You will not be identified by name in any reports and findings will be reported in the aggregate. Please review and complete the informed consent form.

Do I have your permission to record the interview? Microphone ON.

<u>Background Information</u>

- In which department do you work?
- What is your rank? (e.g., professor, assistant professor, graduate student, postdoc, etc.)
- How many people are in the lab group? (ask about: # undergraduates, # graduates and # postdocs)
- How many years/semesters have you worked with undergraduate research students?
- How many undergraduate research students are you currently supervising? How long have you worked with that student?
- Do you plan to continue serving as an advisor to [program] undergraduate research students? Why or why not?
- How did you "find" a [program] student to work with you on your research?

<u>Nature of the Research Project</u>

- Give me a brief overview of the project that your undergraduate research student(s) has been working on – remember I am not a biologist! (or whatever)
- And how is that project going? Do you feel the student has made some progress?
- How much time does the student spend in the lab each week?
- What does the student do in the lab?

<u>Student Gains from Research</u>

- What do you think undergraduates get out of doing research: personally, professionally and scientifically?

(e.g., listen for/probe for: skills, knowledge, thinking and working like a scientist, changes in how students learn, personal growth, self-confidence, perseverance, teamwork, career gains/plans)

<u>The UR experience: Lab interactions</u>

We're interested in how the everyday work in your research group or laboratory took place.

- Tell me about the process of preparing your student to conduct research.

  Probe for: setting rules and expectations, teaching techniques, journal articles
- What kind of support did your student need at the beginning of the research experience? How did you provide that support?
- What kind of support does your student need now? How do you provide that support?
- Describe your interactions with your student. How often do you talk/meet? What do you discuss? (probe for: discussing data, interpreting findings, planning next steps, help with/reviewing posters, educational/career advice)
- How are interactions in the lab structured? Do you have regular meetings? How do lab members communicate with each other about their work?

<u>Preparation for Advising</u>

- How would you rate your preparation for advising undergraduate research students?
- In what ways do you feel well prepared to work with undergraduates?
- In what areas could you use more preparation or support?
- What has most helped your ability to supervise undergraduate research students?

<u>[Program] Mentor Training</u>

- Did you attend the [program] undergraduate research mentor training?
- Do you use anything from the training in your work with undergraduate students? What do you use? Can you give me an example?
- What did you learn from the training?
- What was most helpful to you about the training?
- What could be improved about the training?

<u>Costs and Benefits of Advising Undergraduate Students</u>

- What are the benefits of advising undergraduate students in the lab?
- Have you gained anything from working with undergraduates? (probe for personal, professional gains: mentoring or teaching gains, research productivity, patience, preparation for future faculty career, etc.)
- What are the costs, or drawbacks, to advising undergraduate students?

  If a graduate student or postdoc, do you think your experience advising undergraduate researchers will be useful in your future career? Why or why not?

<u>Advice</u>

- If you could give advice to the people in your research group about how to work with undergraduates, what would you tell them?
- If you could give advice to the [program] staff about their program or training, what advice would you give?