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Key actions of successful summer research mentors

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Abstract Summer research opportunities for undergraduates, such as those supported by the National Science Foundation's Research Experience for Undergraduates (REU) program, can be critical experiences that help persuade students to pursue research through graduate studies. Studies analyzing the key actions of successful mentors are scarce. The goal of this study was to explore how hypothesized "key actions" of mentors correlated with student perceptions of mentoring and of overall program quality, students' scholarly output resulting from the REU, and the influence of the REU on students' decisions to pursue graduate school. Students who participated in 11 REU programs at a large Midwestern US university in summer 2012 were surveyed in spring 2013 about their experiences in the program and with their primary research mentor. Results suggest that the key factors hypothesized to be associated with good mentoring correlated with students' ratings of their relationship with their mentor, students' overall program ratings, students' scholarly output resulting from the REU, and the influence of the REU on students' decisions to pursue graduate school. The six "key actions" hypothesized to be associated with good mentoring were significantly correlated with student experience in an REU program. Although none of the six actions is particularly complex, taking these actions is crucial and non-trivial. Prospective REU mentors could be informed about these key actions during mentor training activities. Future research could examine these six dimensions across postsecondary institutions and in mentoring relationships outside of REU programs.

Keywords REU · Undergraduate research · Mentoring

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Introduction

Mentoring is recognized as a crucial form of teaching in a broad variety of fields, including many science, technology, engineering, and math-related disciplines. One-on-one mentoring relationships and open-ended problem-solving tasks contribute to the value of mentoring (e.g., Thiry et al. 2011). However, we are unaware of any work focused on a quantitative analysis of the behaviors characterizing successful short-term mentoring of summer research projects—the closest work of which we are aware is the qualitative study by Thiry and Laursen (2011) exploring the mentoring needs of various students based upon interviews with 73 undergraduate students. The goal of our study was to explore how hypothesized "key actions" of mentors correlated with student perceptions of mentoring and of overall program quality, students' scholarly output resulting from the REU, and the influence of the REU on students' decisions to pursue graduate school.

REU background information

Research Experiences for Undergraduates (REU) programs are National Science Foundation (NSF)-sponsored programs that support undergraduate participation in scientific research. The REU sites typically enroll ten undergraduate students who become involved in research projects at the host institution and sometimes at cooperating partner institutions. These sites are designed to help attract diverse and talented students and prepare them for careers in science and engineering and must specifically seek to attract students from underrepresented groups, from outside the host institution, and from institutions where research opportunities are limited. The REU programs can be conducted during the summer, throughout the academic year, or year-round. Typically, REU site grants are awarded for 3 years (National Science Foundation 2013).

Researchers have challenged the effectiveness of teaching students science in traditional classrooms or lectures (Cobb 1994; Packer and Goicoechea 2000) and suggested that students might learn better under an apprenticeship model (Sadler et al. 2010), professional socialization model (Corcoran and Clark 1984; Seymour et al. 2004), or inquiry-based learning model (Brew 2003). REU programs incorporate aspects of all three of these non-lecture-based learning approaches (Sadler et al. 2010; Seymour et al. 2004). REU programs may also combat the "chilly" and individualistic climates found in traditional STEM classrooms, which could help to improve student grades and conceptual understanding of course material, increase student interest in science fields, stabilize race and gender inequities in the pipeline, and increase student retention rates (Geisinger and Raman 2013; Nagda et al. 1998; Pascarella and Terenzini 2005).

Students who participate in undergraduate research programs experience a variety of positive outcomes, including increased interest in graduate school and intention to enroll in graduate degree programs (Eagan et al. 2011; Gonzalez-Espada and LaDue 2006; Hathaway et al. 2002; Russell et al. 2007; Zydney et al. 2002) and increased retention rates, particularly for African-American and underperforming students (Nagda et al. 1998). They also experience increased cognitive, higher-order thinking, and problem-solving skills (Bauer and Bennett 2003; Sadler et al. 2010; Seymour et al. 2004; Zydney et al. 2002); communication skills (Bauer and Bennett 2003; Seymour et al. 2004; Zydney et al. 2002); confidence (Russell 2004; Sadler et al. 2010; Seymour et al. 2004); ability to apply a range of research skills to scientific problems (Haen et al. 2012); ability to understand scientific findings (Bauer and Bennett 2003; Zydney et al. 2002); content knowledge and familiarity

with important literature (Russell 2004; Sadler et al. 2010; Zydney et al. 2002); and understanding of the nature of science (Sadler et al. 2010). Some studies have also shown that students who participate in undergraduate research are able to clarify their career goals (Bauer and Bennett 2003; Haen et al. 2012; Sadler et al. 2010; Seymour et al. 2004; Zydney et al. 2002) or increase their interest in pursuing careers in science, engineering, and research (Russell 2004; Sadler et al. 2010).

REU programs and mentoring

NSF maintains that high-quality mentoring is crucial for students participating in REU programs. Specifically, NSF encourages principal investigators to provide mentoring training to REU mentors and develop a plan to encourage continued interaction between mentors and students during and after the program. NSF advises that REUs have the greatest impact when mentors can lead students from relative dependence to relative independence from the start to the end of the program (National Science Foundation 2013).

Research supports the idea that mentoring is a crucial component of students' REU experiences. In a study of over 2000 students, Lopatto (2007) found that students' overall evaluations of their REU programs and their ratings of their mentors were moderately correlated. Other research has noted that time spent with faculty mentors and effective guidance from faculty mentors were important predictors of students' ratings of program satisfaction (Russell 2004; Russell et al. 2007). Lopatto (2004) reported that students who decided to pursue graduate education after participating in the REU rated their mentors more favorably than students who decided not to pursue graduate education after participating in the REU, and Zydney et al.'s (2002) research suggested that interaction with research mentors may be critical in students' decisions to attend graduate school and in their career choices. Similarly, Packard (2005) reported that students who abandon science majors reported receiving less science mentoring than students who stay in science majors.

Unfortunately, there is little research illuminating what characteristics mentors should exemplify in order to facilitate learning for students in REU programs (Lopatto 2007; Sadler et al. 2010). Researchers have, however, suggested that it is important for mentors to give students ownership over their research project, facilitate student involvement in the research process and experimentation, give students increasing independence, and include students in the design of the project (Lopatto 2003; Russell 2004). It is also important for REU students to read scientific literature, work both with peers and alongside faculty, and have opportunities for oral and written communication (Lopatto 2003). Mentor roles should also include allowing for open and honest communication between the mentor and student, providing sound technical advice, making the student feel like an integral component of the project team, and relating the research to students' coursework (Russell 2004).

Dimensions of effective mentoring

Based on our experience in overseeing eight cohorts of summer undergraduate REU participants in three unique programs over 18 program-years, and in evaluating multiple REU programs, we developed a set of hypotheses regarding key actions that typify good mentoring. In some cases, the hypothesis was driven by failures we noted during that time; that is, we considered cases where an internship had gone poorly and reflected on the mentor actions (or lack thereof) that contributed to the problem. We also reflected upon the results of multiple years of REU program evaluations (including pre-program and

post-program surveys, post-program focus groups, and follow-up surveys) and noted, in particular, student comments related to their experiences in the program and with their mentors. Relevant literature related to mentoring was also noted and is discussed in more detail below. The six hypothesized key dimensions of effective mentoring were as follow:

- *Safe*—effective mentors teach students about laboratory procedures and safety protocol.
- *Prepared*—effective mentors are ready for their REU students—they have the necessary supplies and equipment and have ideas or a plan for the student's research project.
- *Proactive*—effective mentors monitor the student's progress and make meaningful changes when problems arise.
- *Patient*—effective mentors are patient and understanding with students.
- *Present*—effective mentors are readily available for students to approach, seek advice, and ask questions.
- *Positive*—effective mentors maintain a positive attitude in the laboratory and giving the student positive feedback on his or her work.

Safety is a critical component in the research laboratory, though it is often overlooked in the literature as an important part of mentoring. Faculty members do not mention Safety as an important component of REU programs because they may believe it was implied or assumed since researchers need to comply with OSHA regulations (Lopatto 2003). In addition, students rate safety training as one of the least valuable components of the REU programs (Lopatto 2003). However, any time students are working in a research laboratory with potential hazards, discussions about how to stay safe are crucial, and mentoring training programs should discuss the need for mentors to cover this topic with their mentees (e.g., Handelsman et al. 2005).

Being Prepared to host an REU student is fundamental. From having a relatively well-defined project in a typical 10-week program to having access to the supplies and equipment needed to complete a project, laboratories and mentors that are Prepared place their interns in position to succeed. A danger is to have an over-defined project in which interns have no input (Lopatto 2003; Russell 2004), but a realistic project with a high probability of success and some flexibility allowing students to branch off of the original ideas or try new techniques (Handelsman et al. 2005) is a way of addressing this challenge.

Researchers have found that students learn problem-solving skills while participating in REU programs (Bauer and Bennett 2003; Seymour et al. 2004). Research has also suggested that students learn these problem-solving skills, in part, by watching their mentors be Proactive, solve problems, and overcome obstacles themselves (Seymour et al. 2004). Thus, mentors should be Proactive and model problem-solving behavior for their mentees (Handelsman et al. 2005; National Academy of Sciences et al. 1997); particularly, we believe, in the context of handling changes in the project (or adjusting to student capabilities or equipment availability).

Patience is crucial when working with students who may be inexperienced or unfamiliar with laboratory procedures and how a professional laboratory functions. Patience is also included as an important factor in the Handelsman et al.'s (2005) guide to mentoring students effectively. Handelsman et al. (2005) state that good mentoring is characterized, in part, by good listening, understanding, and empathy.

Time is a valuable commodity for faculty members and graduate students, but being Present and available to REU students is essential. Handelsman et al. (2005) and the National Academy of Sciences et al. (1997) similarly suggest that it is important to "keep in touch"

with mentees, and ideally check in with the student at least daily. The National Academy of Sciences et al. (1997) report that "a good mentor is approachable and available," while noting that good mentoring is not necessarily time intensive since it may only take a few minutes to check in with a student or respond to a question. Similarly, Wilson et al. (1974) note the importance of a teacher's accessibility and availability on a student's development.

Positivity, in the form of a positive attitude and positive feedback, is also important. Handelsman et al. (2005) point out that even just saying "you can do it" to an uncertain student can make a big difference.

The primary goal of this study was to explore how hypothesized "key actions" of mentors correlated with student perceptions of mentoring and of overall program quality, students' scholarly output resulting from the REU, and the influence of the REU on students' decisions to pursue graduate school. A secondary goal was to determine whether and how a mentor's status (faculty, staff scientist, postdoc, or graduate student) and amount of contact with mentees impacted the REU experience. Since this study represents the first use of the Dimensions of Mentoring survey, it was hoped that the results would help expand and provide insight to improve the survey instrument for future research. This study focused specifically on students who participated in an REU program at a large Midwestern university during the summer of 2012.

Methods

Participants

Active REU programs at a large Midwestern US university were identified by searching on the university website, searching the NSF awards database, and subsequently contacting relevant university personnel. Eleven NSF-sponsored REU programs and one USDA-funded summer internship program were identified. Principal investigators for each REU were contacted and asked for permission to survey students who had participated in the 2012 summer REU programs. Eleven of 12 PIs gave permission to survey their REU students and provided student contact information. These 11 REU programs were all in STEM fields and were highly interdisciplinary, with ties to fields such as agriculture, biology, chemistry, engineering, and human–computer interaction.

A total of 116 students participating in the 11 REU programs took part in this study. An average of 10.5 students participated in each REU program, with the smallest REU hosting four students and the largest hosting 14 students. Students from the participating REU programs were sent an email in the following spring semester (March 2013) inviting them to participate in an online survey that asked about their experiences in the REU program and the actions of their REU mentor. Seventy-six students responded to the survey, resulting in an initial response rate of 65.5 %. Responses from ten students were excluded from the analysis because the students did not report complete data or because they indicated that they did not have a mentor while participating in the REU program, resulting in 66 student surveys with valid responses.

Materials and procedures

Surveys completed by each student consisted of three sections. In the first section, students were asked who served as their primary mentor; how many contact hours they had with

their primary mentor, laboratory PIs, or other members in the laboratory group; and the value of various REU program activities (e.g., hands-on experience in laboratory, mentoring by faculty members, and poster development) using a 7-point Likert-type scale anchored by 1 = *not valuable at all* and 7 = *very valuable*. The primary mentor was defined as the person who oversaw the student's day-to-day activities in the laboratory and would have been most familiar with the details of the student's work; e.g., faculty member, graduate student, and postdoctoral research associate. The students in these programs would all have had faculty mentors who may or may not have served as the student's primary mentor.

The second section of the survey focused on an assessment of students' REU experience. Specifically, students were asked to report their level of agreement ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) with statements indicating whether their experience influenced their decisions to pursue graduate school and/or feeling that they made intellectual contributions to research in their respective host laboratories. Two questions asked whether students are or will be coauthors on a published paper and/or paper presented at a professional meeting. Using a 5-point Likert-type scale ranging from 1 (*poor*) to 5 (*excellent*), students were asked to rate the following REU experiences: laboratory experience, mentoring, social experience, seminars/lectures, tours, and overall experience. Students were also asked to rate the quality of their relationships with their primary mentor, laboratory PI (if different from primary mentor), and others in their laboratory, using a 5-point scale ranging from 1 (*very poor*) to 5 (*very good*).

The final section of the survey was comprised of the 29-item Dimensions of Mentoring Scale (shown in Table 1). The items on the scale were developed to assess students' attitudes toward mentoring along the six dimensions previously described. For example, questions were related to Safety (e.g., my mentor emphasized the importance of laboratory safety), Preparedness (e.g., clear laboratory protocols and techniques were provided to me), Presence (e.g., my mentor helped me become familiar with the tools and equipment available in the laboratory), Positivity (e.g., my mentor gave me positive feedback on aspects of my work at least once a week), Proactive behavior (e.g., my mentor stayed engaged in my project through the duration of the program), and Patience (e.g., my mentor was patient and understanding when I asked questions). Students were asked to indicate the extent with which they agreed with each statement on a 5-point Likert-type scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

Results

Total scores for the dimensions—Safe (three items), Prepared (nine items), Present (nine items), Positive (two items), and Proactive (five items)—were computed by summing the scores for each item within the particular dimension and standardizing (Table 1). The dimension Patient was assessed by one item and so was used as an individual item. Student responses to each of the 29 items within the dimensions of mentoring tended to be skewed to higher ratings (means ranging from 3.41 to 4.55 on the 5-point scale), with the majority of students indicating that they agreed with each item of the scale.

The scores for the computed dimensions (Safe, Prepared, Present, Positive, and Proactive) were found to be highly reliable, with Cronbach's alphas ranging from .71 to .90.

Corrected item–total correlations within each dimension were all positive and significant ranging from .29 to .83, indicating that the dimensions have a high level of internal consistency (Table 2).

Table 1 Dimensions of mentoring—item mean responses

Mentoring items by dimension	M	SD
Safe		
My mentor emphasized the importance of laboratory safety	4.23	.70
My mentor never placed me in a position where I was doing something hazardous that I felt unprepared to do	4.55	.83
My mentor always took proper safety precautions in the laboratory	4.41	.68
Prepared		
My mentor tailored my project to me based on my education and abilities	4.21	.97
My mentor had realistic expectations of me	4.33	.83
My mentor provided me with opportunities to contribute intellectually to my project	4.35	.79
My project was well defined before my arrival to the REU/internship program	3.42	1.30
When I arrived for the program, everyone in the laboratory (the laboratory PI, my mentor, and others in the laboratory) knew what my project was going to be	3.52	1.15
The project I was given had clear goals	4.05	.94
The equipment and materials I needed to do my project were ready when I needed them	4.18	.98
Clear laboratory protocols and techniques were provided to me	4.32	.73
My mentor provided me with the background reading necessary to complete my project	4.24	.80
Present		
My mentor indicated to me the importance of my project	4.20	.79
My mentor inspired me	4.08	1.11
My mentor provided personal protective equipment (PPE) and safety training	4.17	1.00
My mentor introduced me to everyone in the laboratory	4.41	.70
My mentor helped me become familiar with the tools and equipment available in the laboratory	4.23	.82
My mentor set clear expectations for the ethical conduct of research	4.23	.78
My mentor encouraged me to ask questions	4.44	.81
My mentor was readily available if I had questions	4.24	1.12
My mentor and I had regular discussions about the progress of my research	4.30	.96
Positive		
My mentor gave me positive feedback on aspects of my work at least once a week	4.21	1.03
My mentor maintained a positive attitude	4.42	.84
Proactive		
My mentor stayed engaged in my project through the duration of the program	4.32	.96
My mentor and I had scheduled weekly discussions	3.95	1.10
When things were not going as well, my mentor tried to understand why	4.29	.89
My mentor helped me to solve any problems that arose in the laboratory	4.40	.70
My mentor set clear expectations regarding a work schedule and communication with others in the laboratory	4.06	1.02
Patient		
My mentor was patient and understanding when I asked questions	4.41	.89

$N = 66$

The overall REU experience was positively rated by participating students. A small percentage (18.2 %) indicated that they had a "good" overall REU experience, while the majority of students (81.9 %) of students indicated that their overall REU experience was

either "very good" (45.5 %) or "excellent" (36.4 %). The lack of variability in responses to this question is a challenge in the analysis—there were simply no students who reported having poor or very poor experiences.

Correlational analyses were conducted to determine whether the various dimensions of mentoring were related to students' ratings of their experiences, their relationships with mentors, whether their experiences influenced their decision to pursue graduate school, and their overall REU experience (Table 3). Statistically significant correlations ($p \leq .01$) were found between each dimension of mentoring (i.e., Safe, Prepared, Present, Positive, Proactive, and Patient) and students' overall REU experience, indicating that in general, students who thought that their mentors made them feel Safe and were Prepared, Present, Positive, and Patient were more likely to indicate that they had a very good to excellent overall REU experience.

The relationships of selected variables, including primary mentor, number of contact hours with primary mentor, value of REU activities on continued studies, influence of the REU experience, opportunities for contribution to scholarly activities, ratings of REU experiences, and quality of relationships in the laboratory, with the dimensions of mentoring and overall experience in the REU were examined through descriptive (Tables 4, 6, 7, 9) and correlational analysis (Tables 5, 8, 10).

Relationship of primary mentor to dimensions of mentoring and overall experiences

REU primary mentors were primarily comprised of faculty (27.3 %) and graduate students (50.0 %), with some postdoctoral research associates (13.6 %) and other staff scientists (9.1 %) taking on the role of mentor. Perhaps unsurprisingly, the number of contact hours with the primary mentor was generally greater when the primary mentors were graduate students, postdoctoral research associates, or other staff scientists than when the primary mentor was a faculty member. The majority of faculty members (77.8 %) serving as mentors spent <20 h per week with students, while the majority of graduate students (66.7 %), postdoctoral research associates (66.7 %), or other staff scientists (83.3 %) serving as mentors spent 20 h or more per week with students (Table 4).

The number of contact hours students had with their primary mentor was related to students' rating of the quality of the relationship they had with their mentors when their primary mentors were graduate students ($r = .36$, $p = .04$) or another staff scientist

Table 2 Cronbach's alpha and range of correlations for dimensions of mentoring scale

Dimension	Cronbach's alpha (α)	Range of item–total correlations
Safe	.71	.44–.71
Prepared	.86	.46–.72
Present	.89	.29–.79
Positive	.90	.83[a]
Proactive	.89	.61–.78
Patient*	*	*

* α not calculated for "Patient" because there is only one item that assesses this dimension

[a] Range is not available for the Positive dimension; Positive has only two items

Table 3 Correlations (r) of dimensions of mentoring and overall REU experience

Dimension	Overall experience
Safe	**.48****
Prepared	**.53****
Present	**.47****
Positive	**.36****
Proactive	**.48****
Patient	**.31****

$N = 66$; Bold indicates correlations with significant p values, ** $p \leq .01$

Table 4 Number of contact hours by primary mentor

	Faculty		Graduate student		Postdoc		Other staff scientist	
	N	%	*N*	%	*N*	%	*N*	%
Under 20 h per week	14	77.8	11	33.3	3	33.3	1	16.7
20 h or more per week	4	22.2	22	66.7	6	66.7	5	83.3

Table 5 Correlations of overall experience, dimensions of mentoring with variables related to primary mentor

	Dimensions of mentoring						Overall experience
	Safe	Prepared	Present	Proactive	Patient	Positive	
Primary mentor							
Faculty member	−.180	−.106	−.001	−.089	−.091	−.028	**−.298***
Graduate student	.191	.065	.028	.081	.120	−.017	**.254***
Postdoctoral research associate	−.067	.026	−.004	.061	.066	.156	−.039
Other staff scientist	.027	.020	−.042	−.077	−.146	−.113	.067
Number of contact hours with primary mentor							
Primary mentor	**.284***	**.269***	**.310***	**.339****	.217	**.260***	**.254***
Laboratory PI	.115	.154	.183	.222	.173	.229	.165
Laboratory members	.199	−.014	−.048	−.103	−.100	−.037	.047
Quality of relationship with…							
Primary mentor	**.443****	**.537****	**.739****	**.716****	**.667****	**.756****	**.324****
Laboratory PI	.214	**.496****	**.355****	**.298***	.250	**.305***	**.336****
Others in laboratory group	.044	**.280***	.158	.168	.150	.180	.256

$N = 66$; Bold indicates correlations with significant p values, ** $p \leq .01$, * $p \leq .05$

($r = .88$, $p = .02$; results not tabled). In contrast, the number of contact hours was not related to students' rating of the quality of this relationship when their mentors were faculty ($r = .43$, $p = .07$) or postdoctoral research associates ($r = -.02$, $p = .97$).

The type of primary mentor was significantly related to students' ratings of their overall REU experience (Table 5). Interestingly, the overall experience was significantly and positively correlated with having a graduate student as a primary mentor but significantly and negatively correlated with having a faculty member as a primary mentor. This may reflect the challenges associated with having extremely busy faculty members serve as mentors who need regular contact with their mentors. While all students indicated that overall they had a good to excellent REU experience, students whose primary mentors were faculty members were more likely to rate their overall experience as good, while students whose primary mentors were graduate students were more likely to rate their overall experience as very good to excellent. There were no significant correlational relationships between primary mentor and any of the dimensions of mentoring.

The number of contact hours with students' primary mentor was positively related to the following dimensions—Safe, Prepared, Present, Proactive, and Positive and students' overall REU experience. Students who thought that their mentors demonstrated the dimensions of Safe, Prepared, Present, Proactive, Patient, and Positive and who rated their overall REU experience as very good to excellent were also likely to rate the quality of their relationship with their primary mentors as being good or very good. Additionally, the relationship to the laboratory PI was significantly correlated with the dimensions of Prepared, Present, Proactive, Positive, and overall REU experience. Those students who agreed that these dimensions were demonstrated and gave higher ratings of overall experience were also more likely to rate the quality of their relationship with their respective laboratory PI as being good to very good.

Relationship of student ratings of the value of their REU experiences to dimensions of mentoring and overall experiences

Overall, the majority of students indicated that their REU experiences were valuable upon resuming their studies in the next semester (Table 6). The majority (85.2 %) of the students reported that hands-on experiences in the laboratory were valuable in continuing their studies. The majority of students also indicated that mentoring provided by faculty, postdoctoral research associates, graduate students, and other staff scientists was valuable

Table 6 Student ratings of the value of their REU experiences (M and SD)

Type of experience	*N*	95 % Confidence interval*		Mean	SD
		Lower limit	Upper limit		
Hands-on experiences in laboratories	61	5.76	6.50	6.13	1.44
Mentoring by faculty	62	5.13	5.93	5.53	1.58
Mentoring by postdoctoral research associate	36	4.32	5.63	4.97	1.93
Mentoring by graduate student	50	5.35	6.21	5.78	1.52
Mentoring by staff scientist	52	4.85	5.76	5.31	1.63
Technical lecture seminar	62	5.09	5.78	5.44	1.36
Professional development	63	4.86	5.61	5.24	1.49
Poster development	65	5.91	6.39	6.15	.97
Poster presentation	65	6.01	6.49	6.25	.97
Social group events	64	5.47	6.22	5.84	1.49

* Scale: 1 = not valuable at all to 7 = very valuable

(77.4, 63.9, 86.0, and 73.0 %, respectively). Professional development activities (i.e., ethics lectures), technical lectures/seminars, and social events were also rated as being valuable by the majority of the students (69.8, 72.6, and 79.6 %, respectively). Opportunities to participate in developing posters and presenting posters were rated highly valuable by participating students (90.8 and 92.2 %, respectively).

In general, the majority of students rated their REU experiences positively (Table 7). Approximately 71.2 % of the students rated their laboratory experiences as very good or excellent, 19.7 % rated this experience as good, 6.1 % thought it was fair, and only 3.0 % thought it was poor. The majority of students also rated their mentoring (66.7 %), social (75.8 %), attending seminars/lectures (62.1 %), tour (65.1 %), and overall (81.9 %) experiences as being very good or excellent. Approximately 1/5 to 1/3 of the students rated their mentoring (28.8 %), social (21.2 %), attending seminars/lectures (37.9 %), tour (33.0 %), and overall (18.2 %) experiences as being fair or good. Only a few students rated their mentoring (4.5 %), social (3.0 %), attending seminars/lectures (.0 %), tour (1.5 %), and overall (.0 %) experiences as being poor.

The value that students' placed on these experiences was found to be positively related to several dimensions of mentoring (see Table 8). Students who believed that laboratory Safety was emphasized in the laboratory were more likely to indicate that they valued their hands-on experiences, mentoring by faculty members, graduate students, and postdocs. Students who believed that mentors were Prepared and had a project waiting for them were more likely to value the following: (1) mentoring by faculty members, graduate students, and postdoctoral research associates; (2) any technical lectures or seminars attended; and (3) their experiences developing and presenting posters. Students who indicated that their mentors were Present were likely to value mentoring by faculty members, graduate students, and postdoctoral research associates. These students were also more likely to value technical lectures or seminars they attended as well as value their experiences developing and presenting a poster. Students indicating that their mentors were Proactive were more likely to indicate that they valued mentoring by faculty members and graduate students, and students who indicated that their mentors were Positive were more likely to indicate that they valued mentoring by graduate students.

The dimensions of Safe, Prepared, Present, Proactive, and Positive and students' ratings of their overall REU experience were positively related to students' ratings of their laboratory and mentoring experience. In addition, students indicating that they believed that their mentors were Patient were also likely to report that their mentoring experience was very good to excellent. Students that indicated that their social experience, attending

Table 7 Student ratings of their REU experiences

Type of experience	*N*	95 % Confidence interval		Mean	SD
		Lower limit	Upper limit		
Laboratory experience	66	3.76	4.30	4.03	1.08
Mentoring experience	66	3.60	4.18	3.89	1.18
Social experience	66	3.80	4.35	4.08	1.11
Seminars/lectures	66	3.53	3.99	3.76	.95
Tours	66	3.64	4.11	3.88	.95
Overall	66	4.00	4.36	4.18	.72

* Scale: 1 = poor to 5 = excellent

Table 8 Correlations of overall experience, dimensions of mentoring with variables related to value of activities and ratings of REU experience

	Dimensions of mentoring						Overall experience
	Safe	Prepared	Present	Proactive	Patient	Positive	
Value of activities on continued studies							
Hands-on experiences in laboratories	**.288***	.221	.199	.246	.124	.163	**.330****
Mentoring by faculty members	**.281***	**.361****	**.362****	**.306***	.176	.236	**.352****
Mentoring by postdocs	**.433****	**.431****	**.439****	.292	.247	.294	**.484****
Mentoring graduate students	**.374****	**.380****	**.419****	**.367****	.257	**.289***	**.307***
Mentoring staff scientists	.247	.261	.263	.097	.184	.107	**.301***
Technical lectures and seminars	.160	**.400****	**.396****	.298*	.211	.217	**.313***
Professional development/ethics lectures	.020	.183	.211	.184	.087	.143	.243
Poster development	−.035	**.297***	**.249***	.216	.090	.142	.092
Poster presentation	.064	**.346****	**.289***	.226	.154	.163	.179
Social group events	−.006	.065	.076	.129	−.009	.021	**.321****
Ratings of REU experience							
Laboratory experience	**.490****	**.397****	**.364****	**.347****	.226	**.291***	**.605****
Mentoring experience	**.558****	**.717****	**.811****	**.820****	**.626****	**.731****	**.602****
Social experience	.173	.058	.124	.179	.138	.145	**.595****
Seminars/lectures	.091	.077	.100	.100	.028	−.016	**.404****
Tours	.105	.066	.044	.027	−.031	−.026	**.346****

$N = 66$; Bold indicates correlations with significant p values, ** $p \leq .01$, * $p \leq .05$

seminars/lectures, and tours were very good to excellent were also more likely to rate their overall REU experience as very good to excellent.

In general, students who believed they had a very good to excellent overall REU experience were more likely to indicate that they valued their hands-on experiences in the laboratory; mentoring by faculty members, graduate students, postdoctoral research associates, and staff scientists; and technical lectures and seminars they attended, and they placed greater value on social group events.

Relationship of influence of the REU experience to dimensions of mentoring and overall experiences

One of the goals of the REU program is to provide undergraduates with experiences that help them make decisions about graduate school study. Overall, the majority of students (87.8 %) reported that their participation in the summer REU experience helped them decide whether to pursue graduate school, with only a few students (1.5 %) indicating that it did not help them decide whether to pursue graduate school (Table 9). In addition, the

Table 9 Influence of REU experience on decisions regarding graduate school and scholarly activity

	N	Range		Mean	SD
		Min	Max		
Influence of the REU experience					
Decision to pursue graduate school*	66	1	5	4.29	.79
Likelihood of pursuing graduate school*	66	1	5	3.91	1.05
Contributions/opportunities from REU experiences					
Intellectual contribution to research in host laboratory*	66	2	5	3.85	.83
Co-author on published paper[a]	66	1	2	1.80	.40
Co-author on paper presented at a meeting[a]	66	1	2	1.83	.38

* Scale: 1 = strongly disagree to 5 = strongly agree

[a] Scale: 1 = yes to 2 = no

Table 10 Correlations of overall experience, dimensions of mentoring with variables related to value of the influence of the REU experience on graduate school and scholarly activity

	Dimensions of mentoring						Overall experience
	Safe	Prepared	Present	Proactive	Patient	Positive	
Influence of the REU experience							
Decision to pursue graduate school	.196	**.405****	.220	**.264***	**.248***	.131	**.343****
Likelihood of pursuing graduate school	**.276***	**.387****	**.339****	**.304***	**.286***	.219	**.327****
Contributions/opportunities from REU experience							
Intellectual contributions to research in host laboratory	.114	.227	.165	.125	.023	.107	.073
Co-author on published paper	.008	.221	.172	.140	.100	.113	−.087
Co-author on paper presented at a meeting	−.070	−.216	−.212	−.223	−.160	−.205	−.114

$N = 66$; Bold indicates correlations with significant p values, ** $p \leq .01$, * $p \leq .05$

majority (71.2 %) of participating students reported that they were more likely to pursue graduate school because of their REU experience.

Two-thirds of participating students (66.6 %) reported that they made serious intellectual contributions to the research in their host laboratory, 29 % reported they were neutral on whether they made serious intellectual contributions, and only 4 % indicated that they did not make serious intellectual contributions to the research. Approximately one in five students indicated that they are or would be coauthor on a published paper (19.7 %) or a paper presented at a professional meeting (16.7 %) resulting from their REU experience.

Mentors who were Prepared, Proactive, and Present were influential on students' decisions to pursue graduate school and those who provided a Safe environment and who were Prepared, Present, Proactive, and Patient were influential on students' likelihood of pursuing graduate school (Table 10). Students' overall experience also was positively

correlated with their decision to pursue graduate school and the likelihood of pursuing graduate school.

Interestingly, none of the dimensions of mentoring nor students' overall rating of their REU experience were significantly correlated with whether students believed they made serious intellectual contributions to research in their respective laboratories, or whether they were or expected to be a coauthor on any paper (published or presented at a professional meeting) as a result of their experience.

Conclusions

Overview and discussion of findings

It has been well documented that mentoring is beneficial in a variety of settings. In the workplace, mentoring has been found to be related to salary level, promotion rate, and job satisfaction (Allen et al. 2004). In an academic setting, researchers have noted that students who were mentored experienced greater academic success (Crisp and Cruz 2009; Pascarella and Terenzini 1976). Strayhorn and Terrell (2007) noted that research-focused mentoring of black students, in particular, could be related to college satisfaction, college retention, and potentially recruitment into faculty positions. Similarly, Campbell and Campbell (1997) found that minority students who were mentored received higher GPAs and were more likely to persist than were minority students who were not mentored.

This work shows that there are specific mentor actions that correlate with a mentee's overall experience in an REU program. Being Prepared for the arrival of an REU student, being available to students and Proactive about handling changes in a student's project, providing Positive feedback to them on a regular basis, emphasizing and modeling Safety at all times, and being Patient are the foundations of a high-quality REU experience. To a casual observer, especially to one who is unaware of the pressures on typical faculty members, graduate students, scientists, postdoctoral research associates, and others who take on the primary mentoring role, these key activities may sound trivial or obvious. This is a great trap in education—to mistakenly think that the obvious items are being covered, and that the need for knowledge is at an undiscovered frontier. Instead, we argue that—as demonstrated in the results herein—it is often a lack of execution of the obvious that leads to poor outcomes. One approach to avoiding this pitfall is to regularly review these key actions with prospective mentors. In our experience, such a review need not be particularly long—we have used a 15-min podcast combined with a 30- to 45-min follow-up question-and-answer session to help disseminate these practices over the past several years to good effect.

Interestingly, undergraduates generally reported better mentoring from graduate students rather than from faculty. This may reflect the ability for most graduate students to spend more time as mentors than typical faculty mentors (recalling that being Present was an important factor in the list of key actions) and may also reflect the improved learning that occurs when peers (or near-peers) serve as mentors.

Career mentoring and REU mentoring

Mentoring summer REU students is necessarily different from mentoring students in a long-term academic setting or mentoring employees in a career setting. Arguably, the research laboratory might be more like a career setting than a traditional academic setting, but REU students are very short-term, may be inexperienced in a laboratory setting, and

likely require more oversight and guidance than someone in a traditional career setting. Because of these differences, the mentoring behaviors that we hypothesized would be related to student outcomes are necessarily different from the career mentoring and psychosocial mentoring behaviors commonly included in career mentoring theories.

There are, however, similarities between the hypothesized key dimensions of mentoring suggested in this paper and these two theories which are often discussed in the career mentoring literature (psychosocial mentoring vs career mentoring). Being *Patient*, *Present*, and *Positive* could all be considered to be related to the psychosocial theories (which include role modeling, acceptance and confirmation, counseling, and friendship) (Kram 1985; Allen et al. 2004), while the categories of *Safe, Prepared*, and *Proactive* could be considered to be more related to career mentoring (wherein the mentor serves primarily to provide exposure and visibility, coaching, protection, and challenging assignments) (Kram 1985; Allen et al. 2004), though there are fairly significant differences between the ways in which one would likely undertake effective career mentoring in a career setting versus an REU setting.

Limitations and suggestions for future research

Due to the intensive nature of the REU program, the number of students available to take part in this study was limited. The small sample size ($n = 66$) limited our use of exploratory factor analysis (EFA) to evaluate validity of the scale and may have resulted in a statistically nonsignificant association between the number of contact hours with a primary mentor and the students' rating of the quality of that relationship although the effect size of the relationship is large ($r = .43$, $p = .07$, $N = 18$). Increasing the sample size in future studies would help to increase the statistical power needed to detect the effect of these relationships.

Future research could be geared toward refining and validating the Dimensions of Mentoring Scale used in this study. Collection of data from a larger group of mentees might allow sufficient variability that specific areas of strength and weakness could be identified for faculty and non-faculty mentors, perhaps allowing an opportunity for fine-tuning of mentoring training for specific groups of mentors. An expanded study of this sort could be structured to further tease out how mentoring influences student decisions regarding graduate school, which is a central goal of NSF's REU programs. An expanded study could also provide key information for examination of items in the Dimensions of Mentoring Scale and allow for further item refinement—the "patient" component of mentoring could be further teased out, for instance, to add more individual items to the scale in that section, since having more than one item to measure that component would provide a stronger metric.

Another important area for future research to examine is the impact of mentor behaviors and each of the key dimensions of mentoring on underrepresented students and students from institutions with limited research opportunities, since attracting these particular groups of students is also an important goal of the NSF REU programs. Because of the limited sample size, analysis by disaggregated demographics was not possible in this study. Future studies with larger numbers of students should consider comparing the importance of each of the dimensions of effective mentoring behaviors discussed in this paper on students from a variety of institutional and demographic backgrounds.

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