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# Peer and Near-Peer Mentoring: Enhancing Learning in Summer Research Programs

Immersive research experiences in science, technology, engineering, and math (STEM) have long been a mainstay in the preparation of students pursuing careers in STEM fields. A broad range of benefits for such experiences has been demonstrated (Sadler et al. 2009). Whether research training occurs in graduate school, in the form of a thesis or dissertation, or in a high school internship, the goals are often similar: to allow budding STEM professionals to develop the research and analytical skills necessary to successfully engage in a STEM career through the process of experiential learning (Kolb 1983).

The question remains how to optimize research-immersion programs for the benefit of both student participants and the principal investigators (PIs) with whom they work. As important as these internships are to the development of young researchers, the management of large numbers of students is not easy. Further, providing a meaningful research experience requires a significant investment of time on the part of the research mentor in providing training and oversight, which can detract from time spent on activities that might lead more quickly to the development of a publication or another measure of success in a faculty member's field.

As a result, the role of peer mentors and near-peer mentors is receiving attention as a strategy to provide more high-quality research experiences. This strategy extends an individual's group of potential mentors to include, as part of a mentoring network, other students with various levels of research experience (e.g., from novice to expert).

Peer mentoring and near-peer mentoring show potential benefits for both PIs and research students. Peer mentoring includes the collaboration of students who have backgrounds similar to those of the undergraduate researchers, for example, similarity in age, educational background, and/or laboratory experience, whereas near-peer mentors may differ in some of these parameters, but be very similar in others, for example, an undergraduate mentoring a high school student.

The increased use of near-peer mentors may free up the time of more-senior lab members (Ramani, Gruppen, and Krajic Kachur 2006), and may provide a larger network of collaborators when novice researchers need immediate feedback or direction, eliminating costly "down-time" on their research projects. Peer and near-peer mentors also may be more accessible and approachable than the PIs. This is particularly true when the novice researcher does not identify yet with a PhD-level scientist. Thus, near-peer mentoring has also been suggested as a way to help students otherwise unlikely to remain in STEM fields (Dannelly and Steidley 2002). Near-peer mentoring can be an effective way to manage labs that include both high school and undergraduate students (Hanauer et al. 2006). This approach allows for the students with more experience, regardless of age, to serve as a peer or near-peer mentor on a research project, which can also enrich the experience of the student mentors and result in a number of learning gains for the peer-mentors themselves (Sales et al. 2006).

## Mentored Research Programs at Bradley University

Summer research opportunities at Bradley University are offered through a variety of parallel programs. High school students, educators from pre-kindergarten through the 12th grade (pK-12), and undergraduates all can take part in the Building Excellent Scientists for Tomorrow program (BEST). Undergraduates also can participate in a Research Experience for Undergraduates (REU) program through our NSF funding, and two professional master-of-arts programs in Math, Science and Technology Education (MST) are available for elementary and secondary educators. All programs include a mentored, 150-to-400 hour research-immersion experience in a STEM field. Mentors include scientists and engineers at the university and at a variety of research institutions in the area, including hospitals, an environmental-planning group, a medical school, and a U.S. Department of Agriculture laboratory. The culminating event for all summer programs is a research symposium held in August that includes both oral presentations and a poster session.

Table 1: An Overview of the Participants in Bradley University's Summer Research Immersion Programs.*

| | PhD-level Mentor | Undergraduate Peer-Mentor Coordinator | Undergraduate Mentors | Undergraduate Researchers | pK-12 Teacher Researchers | High School Student Researchers |
|---|---|---|---|---|---|---|
| BEST | X | X | X | X | X | X |
| REU | X | X | | X | | |
| MST | X | | X* | | X | |

* Not all teachers are placed in research labs with undergraduate peer mentors, but all are integrated into the larger research community and interact with learners at all levels.

The nature of these summer programs means that research teams are diverse. A given lab may include participants from BEST, REU, MST, or any combination, as well as other undergraduate and graduate students in STEM fields. The educational backgrounds of the novice researchers can range from a high school course or two to an undergraduate degree in a STEM field. Laboratory experience likewise is varied. These differences provide opportunities to explore STEM from multiple perspectives, but also represent challenges for the primary investigators, who have the responsibility to be productive researchers in addition to being research mentors. In order to maximize productivity without losing the benefits of mentorship, we determined that our diverse research teams needed diverse leadership as well. The result was our program of peer and near-peer mentoring.

In 2008, the directors of the BEST program, in cooperation with undergraduate and graduate students, developed a peer and near-peer mentoring system anchored by undergraduate research students (Morris, McConnaughay, and Wolffe 2008). This change formalized the interactions already occurring in the labs, where inexperienced researchers, be they high school students or pK-12 educators, would seek the help of undergraduates who had spent more time in research settings. The position of undergraduate peer-mentor coordinator (UPC) also was created to help train the undergraduate peer mentors, organize social events, and handle other logistical concerns, including seminar scheduling and poster printing for the annual research symposium. A comparable position was added to the REU program as well (Table 1).

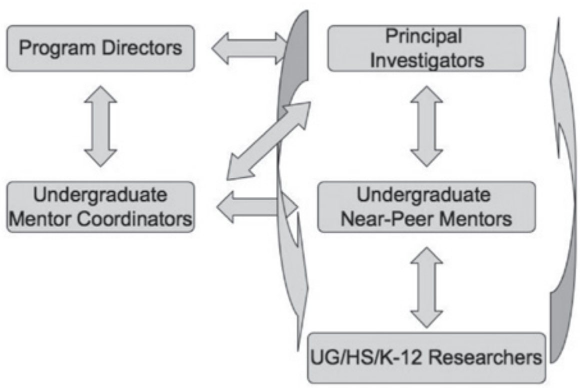
Summer research programs at Bradley, particularly the BEST program, were designed to increase pK-12 educators' preparation in STEM areas and to engender interest in STEM careers among high school students, particularly those from underrepresented groups (Morris, McConnaughay, and Wolffe 2008). Bradley University is located in the heart of a large, urban school district in which almost 70 percent of the student population consists of African-American children from very low-income, often single-parent households.

The development of undergraduate near-peer mentors included the goal of developing the collaborative skills, including communication skills, that undergraduates need for a productive career in a STEM field. Early development of these communication skills potentially can add value to the experience of not only the undergraduate researchers, but also of the pK-12 educators, high school students, graduate students, and PIs, because these near-peer mentors help bridge the sometimes-wide communication gap between new student researchers and senior faculty (Figure 1).

## Undergraduate Mentors' Training and Responsibilities

In our program, both PIs and undergraduate near-peer mentors participate in a variety of workshops and other events designed to enable effective mentoring. These can be broadly described as seminars, workshops, and social events. Some are focused on the development of specific skills, such as oral communication, while others provide opportunities for socializing across research groups and research programs (Table 2). Undergraduate near-peer mentors take a role in these seminars as presenters, organizers, active research participants with high school students, or some combination of these.

Figure 1: Flow of information within mentored research programs. Undergraduate near-peer mentors bridge a potentially large gulf between novice researchers and primary investigators.




At the outset of the summer programs, the UPCs run a workshop for the undergraduate near-peer mentors. Later in the summer, another mentoring workshop is conducted that includes all of the mentors, including PIs. Participants work in groups with several levels of mentors (i.e., PIs with undergraduate near-peer mentors, but from different labs) on selected case studies that outline typical difficult situations that arise in mentor-mentee relationships. Both workshops include formal and informal discussions on effective mentoring. Informally, the workshops allow leaders from throughout the program to interact and see the full scope of the summer research.

Throughout the summer, group cohesion and a sense of community are developed through instructional workshops that bring together undergraduate near-peer mentors, REU students, and high school students. These joint workshops serve to reinforce the students' interaction with their undergraduate mentors; these shared experiences provide easy topics for socializing among the high school students, pK-12 educators, and undergraduate near-peer mentors, while simultaneously providing important training. Seminars and workshops cover topics including scientific design, lab safety (such as materials handling, protective equipment, and interpretation of material safety data sheets (MSDS), and the National Fire Protection Association (NFPA 704) system for identification of hazardous materials); ethics (such as proper citation formats, avoiding plagiarism, and maintaining a lab journal); and statistical analysis (including standard deviation and standard error, as well as a brief discussion of more complicated analytical constructs). These workshops not only introduce or refresh proper lab protocols and tools for participants, but also convey the expectation of at least a minimal level of expertise in these topics for everyone involved.

Workshops range from one-hour introductions to a topic to all-day events. The all-day workshop on scientific design, for example, allows participants to develop and implement a mini-experiment. Undergraduate near-peer mentors are grouped with the high school students with whom they will work during the summer. During the morning session, these groups develop testable questions (e.g., on cardiovascular function) and hypotheses before designing protocols. In the afternoon the groups collect and analyze data and then share their results. While faculty members lead the workshop, undergraduates provide iterative feedback to the high school students, sharing their experience without dictating the course of the experiments. In this way, undergraduate near-peer mentors and high school students begin to collaborate in a low-key environment, and common vocabulary is developed.

In addition to faculty-led workshops, UPCs lead seminars on how to give poster and oral presentations, offering the students a perspective on the challenges facing inexperienced scientific presenters. The undergraduates share their presentations with program coordinators in advance of the workshops, and incorporate suggestions or modifications as needed. This format frees the high school students to ask honest questions that they may not feel comfortable asking PIs or more-senior mentors, such as graduate students (Ramani Gruppen, and Krajic Kachur 2006), and challenges the undergraduate near-peer mentors to communicate their ideas clearly and effectively. One week after the workshops, high school and undergraduate students give practice presentations to the rest of the department and receive discreet comments from the coordinators, mentors, program directors, and other faculty members. This provides the opportunity to become familiar with answering ques-

Table 2: An Overview of Development Workshops and Events for Undergraduate Near-Peer Mentors.*

| Workshop/Event | Organizer | Participants | Time (hours) |
|---|---|---|---|
| Peer mentoring | UPC | BEST | 2 |
| Scientific design | Faculty | BEST | 7 |
| Safety | Faculty | BEST, REU, MST | 1.5 |
| Statistics | Faculty | BEST, REU | 2 |
| Ethics | Faculty | BEST, REU | 2 |
| Mentoring | Program director | BEST, PI | 2.5 |
| Oral presentation/poster design | Faculty, UPC | BEST, REU, MST | 1 |
| Research seminars | PI, UPC | BEST, REU, MST, PI | 10 |
| Presentation practice (group) | Faculty, UG peer mentors, PIs | BEST, REU, MST | 2 |
| Presentation practice (individual) | UG peer mentors, PIs | BEST, REU, MST | varied |
| Breakfast meetings | Program director, UPC | BEST, REU, MST, PI | varied |
| Informal peer mentoring | UPC | BEST | varied |
| Social events | UPC | BEST, REU, MST, PI | varied |

*While total time may vary, all near-peer mentors receive more than 20 hours of professional development.

tions in a live setting and to prepare for some questions that may be asked during the symposium.

The UPCs are in charge of maintaining group dynamics, and serve as a direct line of communication for participants regarding personal needs and social problems. For REU participants, the UPC also provides logistical help with lab work, ensuring students have access to the facilities, equipment, and consumable supplies necessary for their research. To develop a learning community with participants from multiple programs, UPCs organize social events and field trips, such as group breakfasts, cookouts, trips to local festivals, and outings to local minor-league baseball games. UPCs also aid in background logistics, ensuring equipment, food, and notifications are ready for seminars and departmental events.

## Evaluating the Program

Since its inception, the BEST program has been the subject of robust external evaluation. Prior to 2008, the REU program directors administered surveys to evaluate the experience of the REU participants. However, in 2008, when we formally and thoughtfully merged the REU and BEST programs and developed the peer-mentoring component, we revised and combined the evaluation plans for both programs, and then contracted with an external evaluator to carry out the evaluation plan.

The new program evaluation plan used a mixed-methods approach. Surveys were administered to students at the mid-point of the program and after the culminating symposium. The midterm surveys consisted of open-ended questions asking respondents to assess their gains in knowledge of scientific concepts, science processes, and understanding of teamwork; to outline the challenges of the program; and to make suggestions for programmatic improvements. The final surveys were similar to the midterm evaluations, but added an evaluation of the PI and an eight-item, Likert-scale questionnaire focused on gains in knowledge and understanding in specific research-related areas (scientific process, data collection, how to be a productive team member, ways to present information and data, how to work in a lab safely, future career plans, and work ethic).

In 2009, 11 undergraduates, representing 76 percent of the undergraduates in the BEST and REU programs, completed the final survey in its entirety; two more undergraduates completed all but the Likert-scale question. The composite score for all eight items was 3.2 on a four-point scale. In 2010, 10 undergraduates, representing 91 percent of the undergraduates in the program completed the final survey in its entirety, with a composite score for all eight items of 3.6. This indicated that students on average felt they learned between "a good bit" and "a great deal" about both hard scientific skills (e.g., data collection) and soft skills (e.g., teamwork, work ethic). Responses to questions suggested that students felt they learned the most about the scientific process, how to present, how to gather data, and work ethic; this was followed by gains in knowledge about what scientists do, how to work in a lab, how to work in a team, and what to do for a career.

A survey was administered to PIs at the conclusion of the summer program that paralleled the structure to the form administered to students. Open-ended items elicited the PIs' opinion of gains in the student researchers' conceptual understanding; lab culture (e.g., teamwork, tasks, and interactions); suggestions for the future of the program; challenges as a mentor; personal and professional benefits of the program; and suggestions for support for the mentors. An eight-item, Likert-scale questionnaire asked for the PIs' perspectives on students' gains in the same research-related areas that students were asked to evaluate.

In 2009, three PIs completed the final survey. The composite score for all eight items on the Likert-scale questionnaire was a 3.4 on a four-point scale. In 2010, three PIs completed the final survey with a composite score of 3.3. This indicated that the mentors rated their students' learning on both hard and soft scientific skills between "a good bit" and "a great deal." While the overall response rate was low, these results indicate that PIs saw the same degree of growth in their research students as the students saw in themselves. Also similar to the students' assessment, PIs felt students made the greatest gains in understanding of the scientific process, how to gather data, and how scientists do their work.

Additional qualitative methods used for data collection included interviews with students and focus-group discussions. The external evaluator also visited workshops, research laboratories, and the culminating research symposium. Field notes from these events were then analyzed for common themes and experiences.

## Additional Benefits

Evaluation of surveys from participants in the 2009 BEST program noted the value of teamwork at all levels of the program. Responses from surveys mentioned the importance of using the talents of partners in the lab and being considerate of others in shared workspaces. Perhaps most importantly, students learned to view STEM work as collaborative and teamwork as essential. They discussed how the team approach allowed participants to learn more and to work more efficiently and effectively. Students learned how to adapt to a foreign scientific environment, as well as how to effectively communicate with multiple people in the different roles (including both task-oriented and leadership-oriented) found in a research environment. Coordination between different labs on use of equipment, resources, and projects was seen as vital to the success of experiments, in addition to coordination within a lab. High school students noted that personal sacrifice was necessary when working on a team and that while work in science can often be frustrating, repetitious, and tedious, it can also be rewarding.

BEST and REU participants noted the importance of mentoring. In response to a prompt asking students to "list the qualities of your mentor you have learned from and enjoyed this summer," participants listed a variety of traits, including patience, willingness to help, informative, laid back, knowledgeable, approachable, and enthusiastic. They noted that mentors specifically helped them to learn on their own, use their brains, and taught them "how to be nice when you don't want to be." In 2009 the prompt did not ask participants to specify whether they were talking about a PI or an undergraduate near-peer mentor, but the value of mentors was recognized. In 2010, questions specifically relating to undergraduate near-peer mentors were included in the survey.

This past summer we surveyed the undergraduate near-peer mentors and the high school students regarding working together. Qualitative analysis of the open-ended responses demonstrated two parallel themes. In response to the prompt, "Write a list of qualities of your undergraduate mentor you have especially learned from and enjoyed this summer," the high school students' responses centered on work ethic and aspects of creating a supportive work environment. Regarding work ethic, they noted that their near-peer mentors were determined, responsible, hard workers who never gave up. Comments about the relationship they had working together included mention that mentors explained things well, were willing to help, and demonstrated patience. One high school student wrote that her near-peer mentor never got impatient and as a result they "worked in harmony even when we disagreed."

The undergraduates' responses to being asked the qualities they think are important to have as a peer mentor were consistent with the qualities noted by the high school students. They wrote about work ethic in relationship to needing to be reliable, the importance of following through on things, and demonstrating a positive attitude. Comments about work environment included being empathetic, approachable, enthusiastic, and willing to speak their minds, having a positive attitude, and above all, being patient. They also noted the need for good communication skills and having a strong knowledge base.

Through mentoring less-experienced students, undergraduate mentors found new ways to articulate the nature of their research projects, as well as the purpose of each step in the process. The end result was a richer experience and deeper level of understanding and learning for the undergraduate mentors, as well as for the high school students and pK-12 educators working in the lab. As one peer mentor stated, "I was surprised at how I didn't know as much as I thought regarding reasons we do different things—needing to explain things to someone else has helped me better understand certain details." These gains in understanding and communication skills were noted by the PIs as well. From their point of view, both mentors and high school increased their understanding of the nature of academic STEM careers.

Undergraduates saw increases in communication skills not only as they came to understand the terminology used in their laboratories, but also during presentations. Field notes from the evaluator noted increased fluency of the undergraduate and high school students between the practice session and the final symposium. Undergraduate presentations allowed for detailed communication of procedures, but also idiosyncratic approaches to presentations, which included humor. As one undergraduate was comfortable enough to indicate, "Extracting liver from the rat is very tricky and challenging, it looks like a big snot clot." In addition to the increase in oral communication skills, PIs noted increases in program participants' written communication skills, analytical skills, and ability to modify lab apparatus to meet the requirements of the current experiment.

The increased focus on mentoring provided benefits to the PIs, as well as to the undergraduate near-peer mentors. PIs noted the advantage of having undergraduate near-peer mentors who could help oversee the lab work of a team comprised of individuals with diverse expertise and backgrounds. The PIs also appreciated the mentoring workshops in which they had a chance to see the scope of the entire project and interact with researchers in other locations and other fields. One faculty mentor noted it was a "good experience interacting with other mentors. We are from much different environments." This diversity of environments enriched the mentors' experience of researchers' interactions. The mentoring workshop received an average rating of 4.6 out of five from PIs responding to the 2009 final survey of mentors. This question was not included in the 2010 survey.

Participants did note some limitations of the program. Despite the gains from having the efforts of undergraduate near-peer mentors, PIs noted some challenges they still faced. These included lack of time, difficulty in getting students started in the lab due to institutional logistics, finding adequate work for program participants at all times, their ability to adapt methods and procedures to accomplish stated objectives, and the effort needed to stop micromanaging.

Evaluations yielded specific suggestions for actions that would improve the program. Suggestions included spending more time connecting daily lab work to the larger goals of the research lab; this is a place where future PIs and undergraduate near-peer mentors can work together

Dr. Sherri Morris collects soil samples with the help of Bradley junior Joseph Taura, Bradley senior Jenny Mullikin, Jimmie Parker, a high school student participating in Bradley's BEST (Building Excellent Scientists for Tomorrow) summer research program, and Vanessa Toro, an intern.

to make improvements. Participants also noted that the workshop on how to give a presentation was too close to when presentations were due, a problem that was addressed for the 2010 program. Other suggestions were more practical than programmatic, including a need to share keys with interns, adjust temperature in some rooms, and provide more monetary support for lab supplies.

## Conclusions/Future Direction

As participants engaged in the summer immersion experience, they came to appreciate the true nature of STEM studies. They moved beyond thinking of STEM knowledge as "cut and dried" and saw the team interactions behind the development of ideas. They gained a more sophisticated understanding of the process of scientific discovery through multilayered experiences, including the repetition and the tedium. Participants learned through cross-laboratory interactions and the public sharing of results. They also learned terminology and the conventions of the laboratory, while recognizing the contribution of previous research and funding sources.

Through all these processes, participants joined what Wenger (1998) referred to as a community of practice, in this case a community in which novice and experienced researchers worked together toward enhanced understanding in STEM fields. The undergraduate near-peer mentors, in particular, were able to engage in this community at multiple levels, accepting more responsibility as the summer progressed. The end result was a well-established and dynamic learning culture within the community. Such a learning culture can be a powerful vehicle for underrepresented individuals and researchers alike, strengthening their sense of scientific inquiry and community. A learning community helps break the isolation of scientific discovery, or in the case of high school and undergraduate researchers, allows them to see their part within the scientific community as an important steppingstone into their future.

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