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Essay

A Simple E-Mail Mechanism To Enhance Reflection, Independence, and Communication in Young Researchers

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Providing undergraduates with mentored research experiences is a critical component of contemporary undergraduate science education. Although the benefits of undergraduate research experiences are apparent, the methods for mentoring young scientists as they first begin navigating the research lab environment are reinvented in labs all over the world. Students come to research labs with varied skills, motivations, needs, and dispositions, placing each student and mentor in a unique relationship. How can we help students become aware of their own intellectual progress? How can we encourage our students to take initial steps toward independent investigation? When do we need to let setbacks happen? We have developed a simple mechanism to address these common problems. Each week, students in our labs answer a series of five questions by e-mail that improve lab communication and help students develop into mature scientists without taxing an instructor's already busy schedule. Our observations, experiences, and student feedback indicate that this approach is a useful mechanism to help faculty who mentor young scientists in the research lab.

INTRODUCTION

Many successful scientists trace the origins of their research careers back to influential experiences as undergraduates working in their first research laboratory. This formative time in a laboratory, when students first do original research, can shape the futures of budding scientists in powerful ways. Current science pedagogy strongly recommends integrating research into the undergraduate curriculum both as a means to educate the public in the methods of scientific inquiry and as a way to stimulate the next generation of scientists (Tobias, 1992; National Research Council, 2003). Moreover, undergraduate or postbaccalaureate research experience is expected for admission to most graduate programs in the sciences. Consequently, providing undergraduates effective mentoring is a critical component of contemporary undergraduate science education (Pfund *et al.*, 2006). Although the benefits of undergraduate research experiences are apparent, the methods for mentoring scientists as they first begin navigating the research lab environment are far less clear. Few mentors received training in effective ways to mentor young students who need to learn not only a lab's specific techniques but also the intellectual methods of approaching research problems and the culture of the research lab environment.

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Considerable attention has been focused on measuring the impact of student research on preparing future scientists (Tobias, 1992; National Research Council, 2003; Lopatto, 2004), yet it remains difficult to determine how good mentoring in laboratory training affects individual students. What can we do, as scientist-educators, to improve our students' research experiences? How can we help students become more aware of their own intellectual progress, which may foster higher levels of learning (Bloom, 1956; Magolda, 1992, 2001; Metcalfe and Shimamura, 1994; King and Kitchener, 1994; Kronholm, 1994)? How can we encourage our students to take initial steps toward independent investigation? If we knew what our students were thinking, would we be better at letting them learn by their own mistakes when minor setbacks happen?

Few of us who supervise new researchers have formal training in mentoring; consequently, most mentors develop mentoring styles by drawing from their own experiences as protégées (Pfund *et al.*, 2006). It is a challenge to find an appropriate balance between micromanaging our students and providing them with independence and space to learn how to be successful in the lab. In addition, students come to research labs with varied skills, motivations, needs, and dispositions, placing each student and mentor in a unique relationship.

REFLECTIVE QUESTIONS IN A RESEARCH LAB

To enhance communication, comprehension, reflection, and independence among our undergraduate research students, we have developed a simple mechanism for gauging student growth, enhancing communication, and modeling the higher levels of thinking necessary for successful research. On a regular basis, we ask our research students to answer these short questions via e-mail:

1. How have you spent your time?
2. What do you know?
3. What don't you know?
4. How can you find out what you don't know?
5. What are your frustrations?

The first two questions stimulate students to document their progress, questions three and four encourage students to identify gaps in their knowledge and ways to fill in those gaps, and the last question allows students to identify and share any roadblocks they encounter in their research and learning.

How Have You Spent Your Time?

By summarizing how their lab time was spent (some of which may occur out of the mentor's sight), the mentor can evaluate student participation and efficiency. Although this documentation is not meant to be a time sheet, it can be very useful in assigning participation grades or noting trends when the level of student engagement may be changing and needs to be addressed in some way. Some new students in the lab are very good at streamlining their work habits, reaching goals, and producing data, whereas others can get sidetracked, overwhelmed, or lost. This straightforward documentation of how lab time is spent can also help the mentor and student identify any issues with efficiency, time management, and research priorities that may arise. Having a student-generated record of the time spent on particular tasks can help the mentor identify areas for improvement. Moreover, question number one can help students appreciate the progress in their skills. For example, a student may need all day to complete a procedure when he or she first learns it, but with time and experience the new investigator may be able to accomplish the same procedure much more rapidly and accurately. By regularly describing how they spend their lab time, students can see how they are improving their technical competence, an important and encouraging accomplishment in the early stages of research that often precedes the production of useful data.

What Do You Know?

By stating what they have learned recently, students can document and appreciate how much they have learned via their research experiences. Student responses to this question range widely from acquisition of specific facts and familiarity with relevant research literature to proficiency in technical skills, protocols, and experimental design. Sometimes they comment on common novice pitfalls, specific insights, presentation strategies, or how to interact with others in the lab. Because the excitement of research findings can be sparse, particularly for new researchers, students often lose sight of their own progress. We find that this question sets an upbeat tone and helps them document new lessons learned since their last entry. In our experience, students have little trouble identifying new knowledge. Moreover, this regular statement of what students have learned in the past week helps both students and mentors appreciate the intellectual gains students are making as they go through the research process.

What Don't You Know?

It is not unusual for students to feel anxious in a new lab environment, but many have trouble identifying the cause of their apprehension. One source of this discomfort can be an inability to recognize holes in their knowledge. Identifying what they do not know is an important first step for students learning to take charge of their own education, think independently, and develop problem-solving strategies. In our experience, college students are so accustomed to being tested on what they know (or are supposed to know), that sometimes they have trouble adjusting to this situation where they are expected to identify the gaps in their own knowledge. We have found that many students come to appreciate this nonthreatening and unusual opportunity to recognize what they do not know. By explicitly encouraging students to define the specific gaps in their knowledge, we can help students acknowledge and approach their uncertainty in a way that encourages them to communicate, problem solve, and ultimately become more productive scientists.

From the mentor's perspective, this question of what a student does not know often identifies critical areas where the mentor may have inadvertently assumed knowledge that the students do not yet have, where students misunderstood important information, or where expectations may have been unclear. We have found this question to be particularly important in our mentoring relationships because many students are more comfortable revealing ignorance via private written communication than speaking in public or even one-on-one. We can respond to their issues directly by supplying answers, or by directing students to appropriate references and resources. In some instances, the entire lab group needs to be informed, so the gaps students identify in this question can be used to structure lab meetings (or other shared time) without putting a student on the spot. Regardless of the format of our response, we can address student needs quickly, thereby reinforcing the value of their communicating openly with their supervisors. Question four (How can you find out what you don't know?) builds on question three by encouraging students to consider active strategies for filling in gaps. Knowing how to find an answer to an open question is an important skill that all successful researchers need to develop.

How Can You Find Out What You Don't Know?

Original research requires technical skills and intellectual maturity in order to trouble shoot, interpret data, and make progress. Few students develop all these traits via traditional lecture and lab courses. In the research lab, the sink-or-swim approach is a common mechanism by which new research students acquire these important skills. Many successful investigators are living testament that a sink-or-swim approach can identify future scientists. Although some students may be natural swimmers who thrive in the research lab, there are students who may not be able to swim on their own at first, but with guidance can be taught to swim, and eventually thrive in the research lab environment. Many people and organizations have called for increased diversity in the science workforce to improve the talent pool of tomorrow's scientists (National Research Council, 2003; Lawrence, 2006). If we continue to apply the same sink-or-swim selection pressure to all students, can we realistically expect different outcomes of our educational system and thus a more diverse population of scientists? It seems clear that we need to provide a range of mentoring options if we are to respond appropriately to the reality that our students are young adults with diverse backgrounds, personalities, and needs.

Rather than fostering recurrent bad habits in weak students, we see questions three and four as a way to support students who need opportunities to grow without hindering the students who may not need such explicit opportunities. By devising their own solutions to self-defined problems, our students begin to take charge of their own education, gaining confidence and independence, and learning perhaps the most important of all skills in science—problem solving. By identifying areas of uncertainty and devising ways to address them, students can raise their level of self-awareness and mature as independent and life-long learners.

What Are Your Frustrations?

Unlike the previous four questions, this question opens the door for students and mentors to address personal problems related to lab research. Many problems that begin as failures of interpersonal communication can result in situations that reduce the efficiency with which the laboratory operates (Cohen and Cohen, 2005). In addition to personality conflicts, students often reveal frustrations over time constraints, poor planning, broken equipment, missing reagents, or inconsiderate labmates. It seems odd that students are reluctant to share such concerns in person, but we have learned from our experiences that some students have difficulty expressing themselves verbally or fear that it is impolite to reveal a weakness or "tattle" on a labmate with whom they are having difficulties. Therefore, the written answers to this question can uncover behavior patterns or communication breakdowns that the students are experiencing but may often be hidden from a busy mentor's view.

Problems between labmates can be addressed early if intervention is required. However, the more common outcome is more effective individualized mentoring. Each student has different needs, and a one-size-fits-all approach to personnel management is often inadequate, especially for younger students. In addition, we want to provide our students with a role model for supervising people and projects by supporting those who would have sunk if left alone. We hope we are encouraging some students to consider a life of research instead of succumbing to pressures to pursue high-profile careers such as medicine, business, or law. For those students who do not continue in science or research, we expect that these five questions will also be a valuable strategy they can use to solve problems, reflect on their progress, and communicate with coworkers in other disciplines as well.

LOGISTICS OF QUESTIONS

Principal investigators typically are busy people with responsibilities that extend far beyond supervising new students in their labs. Consequently, our five-question approach may sound like more busywork that will add to e-mail accounts that are already overwhelming. However, the time commitment of our approach is minimal and the payoff substantial, even time saving, for student learning and meeting our research goals.

We have found that a once-a-week e-mail works well for independent study or group investigation research courses during the academic year. For full-time summer research students, daily answers combined into one week-long document submitted Friday afternoons works very well (Figure 1). Because the submissions are by e-mail, it is easy for us to reply to minor issues. For those issues that require more direct or in-depth communication, we can set up appointments and/or use the next scheduled lab meeting as a forum to reach everyone without singling out an individual student. An added benefit of e-mail correspondence is that we can archive these e-mails in a folder and refer back to them as necessary for documenting student progress for use in letters of recommendation, considering class participation grades, and personal reflections of a semester.

We do not grade student answers to these questions because we view this communication as a mechanism for mentoring rather than evaluating. In fact, we do not require complete sentences or perfect grammar. The questions are meant to foster independence, reflection, and open commu-

Figure 1. Students typing answers.

nication. We feel that answers submitted without formal judgment are more likely to foster honest communication because students often feel that they need to "perform" by supplying the "right answers" for graded assignments. We use these five questions simply and directly to foster trusting and open relationships with our research students and enhance the research productivity of our labs. We hope this approach will lead to stronger relationships and mutual respect that can grow into long-lasting professional relationships.

STUDENT FEEDBACK

This "five questions" method was piloted during the summer of 2005 with four research students. During the 2005–2006 academic year, we used these questions in two group investigation courses. The courses encouraged students to learn new research techniques beyond the scope of traditional lab courses (designing and printing DNA microarrays, immunostaining, confocal microscopy, tissue culture, etc.) in order to answer novel research questions. Students arranged independent work times throughout the week and met in groups with their respective instructor in a weekly lab meeting format. We used the e-mail to identify issues that needed to be addressed during the weekly lab meeting. The five-question e-mails revealed many important issues that could be addressed easily during the lab meeting such as allocation of research time, clarifying research objectives, assigning research tasks, scheduling training times, and addressing conceptual questions. Any lingering or individual questions were addressed by e-mail or in person. At the end of the semester, students commented favorably on anonymous evaluation sheets that asked if the weekly e-mail assignment helped them reflect on what they were learning and communicate with the instructor. Specific comments about the e-mail assignment included:

- "They keep us on track."
- "I found the five questions an excellent time for reflection, reevaluations, and planning for the upcoming week. They also provided a low-stress way to express concerns."
- "Lab meetings were very productive. We got done what we needed to get done quickly and efficiently."
- "I thought the five questions were great, especially the ones that asked us what we couldn't do and how we could go about learning how to do them. This encouraged us to think for ourselves."
- "I think this was very helpful for me. First of all, it made me actually think about what I had learned/not learned and to put my frustrations into words. It was also helpful to let you know what was going on in the lab if we were having problems."

Other comments on the end-of-the-semester evaluations indicated that many of our learning goals of teaching independent thinking and problem solving were achieved, even though the evaluation form did not ask about these goals explicitly. For example, students commented:

- "This whole class involved thinking for ourselves."
- "Communication was key to successfully completing projects in this course."
- "I also have a greater appreciation for the importance of teamwork and accountability in the lab. Honesty and reliability are so key to a successful research group."
- "Constant communication was key. . . . I think if I had been trying to go through all of these experiments and processes by myself, I would have been way more frustrated and way less successful. . . . "
- "I've realized that I really do love researching in the lab and that I can handle the frustrations."

Finally, student responses to a question on advice they would give on being successful in a research course to a friend taking the course in the future revealed that communication, planning, and identifying personal strengths were important lessons learned by our students.

- "I would say that it is important to learn how to communicate with your peers early on. This will be invaluable in the future. Also, plan ahead. If you have your project organized, then you can set goals for yourself, as well as deadlines. That way, when the deadline approaches, you are not frantically rushing to get everything done."
- "Ask questions. Plan ahead. Always leave more than enough time to complete the project at hand. Start working early! Communicate daily with lab mates about progress, questions, tips. Establish good relationships with all lab mates."
- "Start communication with the group members as soon as possible. It helps so much to use each other's strengths . . . . to get the tasks completed. Don't be afraid to ask for help. The sooner you know if you're going in the right direction, the better things will be."

CONCLUSIONS

Asking students to answer these questions is not intended to replace good lab management or dedicated mentoring. We found this efficient, five-question e-mail mechanism goes a long way to establishing good working relationships, open communication, and demonstrating the value of regular reflection on one's progress and challenges with our students. Furthermore, these questions have improved our ability to gauge student progress and attitudes toward research by providing an important window into the minds of our students. When our primary goal is helping students learn more effectively, teaching them how to take the lead in their own education is a beneficial outcome (that does not often appear on standardized tests or course evaluations). The amount of time it takes to implement these questions is directly proportional to the size of the lab. Mentors with more students must spend more time reading and responding to questions, but that time would be well spent if the mentor becomes more fully aware of each student's progress. Regardless of lab size, we feel these questions are a very effective means to improve lab communication and efficiency for young research students. Moreover, these questions have the important potential to reach those students who, due to differences in personalities, are reluctant to contribute during lab meetings or interrupt a busy mentor. If a student knows he or she will be heard at least once a week, the mentor may see increased confidence and public communication. Most importantly, these questions help foster a learning environment that is rewarding, enjoyable, and stimulating for individual growth—exactly the type of environment in which students can discover the joys of science.

Our easy-to-use method is consistent with efforts to use reflective thinking to enhance student learning. For example, Blank (2000) found improved metacognition and the duration of student learning when teachers provided students with additional discussions about their education. Blank (2000) found no difference in the amount of knowledge content as a result of student-teacher discussions on learning. However, using e-mail as a less time-intensive mechanism of communication can improve the quantity of student learning (Smith *et al.,* 1999; Yu and Yu, 2002). Interestingly, Yu and Yu (2002) measured an improvement in knowledge content as a result of additional e-mail communication, but student attitudes toward the subject were not improved. These different results highlight the difficulty in assessing educational gains that can deter many educators from adopting new methods. However, each of these studies demonstrated learning improvements of some kind. Furthermore, Pfund *et al.* (2006) demonstrated that supervisor communication with student researchers is critical to improving the mentoring relationship. Mentors were encouraged to help students gain confidence and independence. In short, regularly scheduled queries of students about their own learning are simple to implement and can improve a student's research experience. Therefore, we will continue to use this reflective e-mail method as one tool to improve undergraduate research training/mentoring.

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