

Five Essential Skills for Every Undergraduate Researcher

"[B]eing my research problem, it was up to me to solve. ...The crucial lesson was that the scope of things I didn't know wasn't merely vast; it was, for all practical purposes, infinite. That realization, instead of being discouraging, was liberating. If our ignorance is infinite, the only possible course of action is to muddle through as best we can (Schwartz 2008, 1771).

Research is hardly easy. As Martin Schwartz points out in his 2008 essay "The Importance of Stupidity in Scientific Research," solving research problems requires us to immerse ourselves in the unknown. However intimidating it may be to overcome this infinite amount of ignorance, we believe there is a special set of traits that will equip an undergraduate researcher to successfully solve research problems. Creativity, judgment, communication, organization, and persistence are all equally important skills to make the leap from gaining knowledge from others' discoveries to making discoveries on your own. Having and honing these skills, skills that encompass every level of research in every discipline, are key to an undergraduate developing the foundation for a successful career in research. As a group of undergraduate researchers and mentors, we want to motivate students to solve problems and make discoveries, and to start a discussion on how to forge the right path for each student toward research success. Following is our list of key skills.

Creativity

It is difficult to find a definition of undergraduate research that does not include a reference to creativity or that does not contain terms such as original, authentic, or unique. Clearly, then, creativity is a constant for the undergraduate research process. In an article by Jeffrey M. Osborn, dean of The College of New Jersey, and Kerry K. Karukstis, professor of chemistry at Harvey Mudd College, originality is said to be a "common thread that runs through every undergraduate research activity on campus." Creativity and originality go hand in hand. Creativity is the ability to transcend mainstream ideas, and creativity all but requires originality. It is no surprise then that originality is so pervasive throughout the college or university campus. The Council of Undergraduate Research provides a universally applicable definition that describes undergraduate research as "an inquiry or investigation conducted by an undergradu-

ate student that makes an original, intellectual, or creative contribution to the discipline" (Wenzel 1997, 2000). All researchers, not just undergraduates, require creative thinking and process development to build upon today's knowledge. Creativity is an essential trait that undergraduate researchers should seek to develop and utilize within their research experience.

The first step in research is developing a topic or a plan for exploring a problem, and creativity is fundamental to this effort. As members of our university's Student Undergraduate Research Council, we constantly come across prospective undergraduate researchers who don't know where to begin. Students in all disciplines are unsure, even lost, as to how they should start deciding upon a research topic. We encourage students to research their discipline extensively, to find out what has and has not been studied, and to attempt to find a topic in which they are genuinely interested. Even by studying research outside their own disciplines, budding researchers can use the creative process to make new connections, pushing the envelope of what is possible in discovery. Ingenuity, uniqueness, and, most importantly, creativity are all skills that need to be applied in creating that standout research concept.

Students who are still hesitant about delving into the creative process of undergraduate research as part of an independent endeavor should seek to develop their creativity by participating in ongoing research and watching how a faculty mentor or graduate student employs creativity in conducting that research. During this time, undergraduate researchers can learn how to think creatively within the context of their field and possibly discover a topic of interest that will provide them with an independent, unique research opportunity. But students should not limit themselves to the expertise of their faculty mentors. To be a true researcher, undergraduates should strive to reach beyond their own disciplines, either into closely related disciplines or those completely unrelated to their own, for possible ideas.

Judgment

A quite specific sort of judgment is critical when participating in the world of research. Just as the mentor may exercise judgment in selecting a mentee, an undergraduate researcher should likewise evaluate and choose a mentor who will help the researcher to grow in the best possible way. Personality,

temperament, and style of research are all factors to consider when choosing a mentor. Another important aspect of judgment is recognizing when to ask for help in solving problems. To gain the most experience from research, students must make a calculation between knowing when to ask for help when they encounter an obstacle or possibly lose time by deciding to tackle the problem on their own. The progress of the research and perhaps the opportunity for the project to be finished successfully may rest on what they decide.

However, student researchers should not over-utilize a mentor's valuable time; instead, they should strike a balance between independence and seeking assistance. As undergraduate researchers move on to higher-level studies and professional careers, this ability to discern their own and others' needs, and thus make judgments in a fluid environment, must become automatic and unconscious, so they do not waste precious time and energy weighing the pros and cons of every single decision.

Undergraduate researchers also should consider and study the importance of good judgment as it applies to ethical dilemmas in research. Failure to exercise good ethical judgments can seriously jeopardize the careers and integrity of not only the student researchers, but also of their mentors, colleagues, and possibly even their college or university. Undergraduate researchers must be careful not to rely solely on the examples set by faculty mentors or fellow students. Additionally, students should spend ample time learning about the ethical issues associated with their particular fields and strive to utilize their own considered judgments to arrive at appropriate, safe, and ethical conclusions. Today's undergraduate researchers should be cognizant of and conversant with common areas of ethical failings, such as misuse and misrepresentation of findings, wrongful disclosure, and even plagiarism. Being aware of potential ethical issues will help to maintain the integrity of the research for all parties involved.

Although it may be difficult to always make the best choices in as unpredictable a world as research, undergraduate researchers have the opportunity to develop ethical and rational decision-making skills in a lower-stakes environment with oversight by experienced researchers. They can, through practical application, gain experience in making ethical judgments. They can learn to recognize the issue at hand (whether it be time conflicts or personality conflicts or something else); determine the pros and cons of each possible way of dealing with the conflict; seek advice from veterans of research; and, when appropriate, take the occasional risk. Studying these different types of decision-making processes (Bennis et al 2010, 191) can help students develop the skills in exercising judgment that undergraduate researchers require. Eventually the skills should become second nature.

Communication

For this article, we refer to communication as the set of skills necessary to develop and maintain an effective relationship between an undergraduate researcher and his or her faculty mentor. The importance of a mentee-mentor relationship to all undergraduate students is best characterized by UCLA's Alexander Astin, who counts these interactions as one of the most important factors in the development of a student's undergraduate experience (Astin 1991). The positive implications of these relationships extend to undergraduate research as well, because these interactions "potentially have the longest-lasting impact" on the undergraduate researcher's personal growth and academic development (Malachowski 1996, 90). Faculty mentors are the most valuable link between the student and the new and unfamiliar world of research. Mitchell Malachowski, in his discussion of the importance of faculty mentors to research projects, states they "encourage and guide the student's personal growth and academic development, while providing support and assistance as the student works through the challenges" of undergraduate research (Malachowski 1996, 90).

Initiating communication with a faculty mentor during the early phases of the undergraduate research process can be an intimidating situation; students sometimes begin the process with faculty members with whom they have little experience. They may be hesitant to contact mentors outside of the predetermined research time at first, worried that their questions could be "annoying" or their concerns "silly." However, in our experience, mentors are more than willing to accommodate students with in-person meetings and email exchanges, or to suggest the use of more-experienced student researchers as "peer mentors" for inexperienced undergraduate researchers.

Nonetheless, undergraduate researchers should be respectful of their mentors and their time; faculty mentors often balance a schedule consisting of multiple courses, their own independent research endeavors, and mentoring of additional undergraduate or graduate researchers. In our experience as undergraduate researchers, however, we have found that the creation and maintenance of productive relationships with our mentors have led to an increased understanding and knowledge of our respective fields, additional research opportunities, and overall enhanced personal and professional skills.

Organization

Well-honed organizational skills facilitate effective research and good science, as well as allowing students to balance classes, studying, research, socializing, hobbies, and maintaining a healthy lifestyle much easier. Keeping an organized

CURQ Vignettes

Dear Mentors/Professors: Tips to Maximize Research Value from Your Undergraduate Research Assistants

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It is a common misconception that success as an undergraduate researcher depends solely on the student's initiative, hard work, and dedication. The contributions of the supervisor in the student-mentor relationship, however, are equally crucial in promoting efficient and sustained undergraduate research (UR).

As a participant in the University of Ottawa's Undergraduate Research Opportunity Program, I was enticed into research by an amazing professor who is not only renowned in his field, but also is able to enthusiastically communicate and transfer his knowledge. While research has been the most intellectually stimulating and useful opportunity of my university career, I soon discovered that many of my peers did not feel the same way about their experiences. In discussion with my fellow researchers, it became apparent that the supervisor's involvement is the key to success. Drawing on my colleagues' experiences, I present a few simple tips for UR mentors that will benefit faculty members' work and improve the accomplishments of their UR assistants.

- **Schedule regular meetings with your undergraduate researcher.** This gives you a chance to check progress, answer questions, and minimize potential miscommunication concerning your research.
- **Communicate your research in layman's term.** Explaining the bottom line and importance of your research motivates your undergraduate assistant by providing an overall goal to achieve.
- **Establish networking opportunities by introducing your student to colleagues and graduate students.** Your researcher will gather resources, develop partnerships between projects, and maximize the return received from the student's investment in your research projects.
- **Express your energy, enthusiasm, and interest.** Passionate leadership results in passionate results!
- **Mutual respect is a two-way street.** Although undergraduates are at the bottom of research hierarchy, consideration and kindness encourage devotion and loyalty on the part of both parties.
- **Provide resources for your undergraduate researcher.** It is surprising how much a designated workspace or computer will encourage work in the lab.
- **Be available to your undergraduate researcher.** Professors will often shift the mentorship role onto graduate students. While a graduate student provides a great resource, the faculty member must also be available to teach and directly guide the undergraduate researchers.

Perhaps the real secret of any successful endeavor is communication!

journal or lab notebook of all work is critical for analyzing data, generating new ideas or proposals, or determining the next step in a project. Most importantly, organized lab notes and data help tremendously in the process of writing papers and publishing work. These skills can make the difference between a solid report and an unsupported essay. An unorganized undergraduate researcher may have a harder time getting work done within any deadlines and may have a more difficult time finding data and relevant notes on past research. As undergraduate researchers, we have all experienced working with a deadline, but our faculty mentors didn't regularly check that we had lab notebooks or sources recorded properly. Without a good organizational structure, it is difficult to finish work in a timely manner, and the researcher is likely to find it difficult to locate the exact data point or specific quote and author when needed. Being able to keep to a schedule of research and other responsibilities, as well as writing effective "to do" lists, will help greatly. Class work, class notes, lab notes and lab work should be

efficiently organized to facilitate better coordination between coursework and research information.

Undergraduate researchers are likely to be involved in a variety of other pursuits and to be incredibly busy, so it is easy for them to reach that "burn out" point. Organization is a key part of avoiding being overwhelmed and can help students avoid over-scheduling themselves, leading to more success in all their commitments. Those who continue to do research will find this skill crucial to balancing multiple or larger projects, as well as to having a healthy life outside of research.

Persistence

Persistence is the drive to never give up. But it is important to realize that persistence involves facing failure. Failure could involve coming up with a bad research design, not anticipating future roadblocks, or not knowing every detail of a proposed research project. However, failure is a normal part

of progress, and we often learn more from our mistakes than our successes, especially in research, where the investigator must consider many aspects of a problem. Many students pass up an opportunity to do research if there is a chance they might not succeed. Mistakes should be embraced as an opportunity to learn, and students should stop harboring a fear of failure. Although it is difficult to remain persistent at times, students must remember that it will pay off in the end, in the form of quality data, a solid synthesis, or even simply an educational experience.

Persistence is especially useful for budding undergraduate researchers who do not have strong resumes or previous experience. It's a trait definitely noticed by most faculty mentors. Sometimes, a faculty mentor will pick a student for his or her lab even though the student has less experience than other candidates simply because the student has displayed strong motivation. Later, when a student is committed to research, persistence is essential to developing and carrying out a thorough project. Students who overcome roadblocks successfully by being diligent in reading the research literature and making use of their faculty mentor's expertise will find that when it comes time to present their work, answering questions is effortless because the students have put in the foundational work. Persistence becomes an increasingly integral part of the research process as student researchers progress to graduate school and future academic endeavors. The majority of researchers must write several grants in order to initiate their research. This process inevitably involves rejection and, therefore, the motivation to rewrite and edit grant applications is crucial to launching the research process and a productive research career.

Conclusion

Applying the five skills outlined above will help an undergraduate transition from being a student to becoming a researcher and move from learning to discovering. Although we come from various backgrounds and research fields and have different personalities, we have found that these skills are common to all of our successes, from attending conferences on human factors in psychology, to writing a thesis on Italian architecture, to restoring oyster reefs, and even to studying molecular genetics in Germany. Creativity, judgment, communication, organization, and persistence are universally applicable in the pursuit of becoming a better researcher. We hope that this set of essential skills will provide a foundation not only for what it means to be an undergraduate researcher, but also will create the opportunity for a dialogue among researchers at all levels, from the undergraduate to the tenured professor, regarding what makes undergraduate researchers truly succeed.

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Adrienne Showman is a senior pursuing her bachelor's of science in molecular biology and microbiology at the University of Central Florida. Having worked in a biochemistry and X-ray crystallography lab for the past year and a half, her research interests include molecular biology and structure determination. She spent a summer abroad in Germany, working at Humboldt University in the Breeding Biology and Molecular Genetics Department through the German Academic Exchange Service: Research Internships in Science and Engineering Program (DAAD RISE). She hopes to pursue a PhD in biochemistry, and enjoys hiking, traveling, and mentoring outside of class and lab work.

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