Undergraduates and Research: Motivations, Challenges, and the Path Forward

Moderator: W. Eric Wong[1]
Panelists: Junhua Ding[2], Gene Fiorini[3], Christian Hansen[4]

[1]*Department of Computer Science*, *University of Texas at Dallas*, *USA*, *ewong@utdallas.edu*
[2]*Department of Computer Science*, *East Carolina University*, *USA*, *dingj@ecu.edu*
[3]*DIMACS*, *Rutgers University*, *USA*, *gfiorini@dimacs.rutgers.edu*
[4]*School of Computing and Engineering Sciences*, *Eastern Washington University*, *USA*, *chansen@ewu.edu*

Abstract

At last year's conference, we organized a panel "Involving Undergraduates in Research: Motivations and Challenges" which was a great success with many interesting discussions. This has motivated us to develop a second iteration of this panel with an additional dimension – the Path Forward. We expect to have more discussions on how to extend what we have already learned from the past experiences to further enhance the way we involve undergraduates in doing research.

Panelists will deliver a 5-minute overview of their research experiences with undergraduate students, including challenges they faced, lessons learned, and areas for improvement. The floor will then be opened for audience members to voice any concerns, questions, or comments. Student panel attendees will be given special consideration when presenting observations from their own perspective.

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W. Eric Wong
Department of Computer Science
University of Texas at Dallas
Richardson, TX 75080

The National Science Foundation is committed to the encouragement and support of undergraduates actively involved in research projects. It is critical that they are exposed to research principles and practices as early as possible, because they will have a better grasp on what a research project is truly about. To accomplish this goal, the NSF's special REU program (Research Experiences for Undergraduates) supports the hands-on participation of undergraduate students in any area of research funded by NSF. Since 2009, the Department of Computer Science at the University of Texas at Dallas has organized an NSF-sponsored REU program (http://paris.utdallas.edu/reu/) with a focus on *Software Safety*. Each summer we recruit 10 students nationwide to spend 10 weeks on our campus working on selected research projects. We emphasize not only the state-of-art research but also the state-of-practice application of cutting-edge techniques to industry projects.

Below we report our experiences in running this REU summer research program and lessons learned during the last 5 years. One of the most important aspects is to create a learning and research environment for undergraduate students to explore their potential in doing research. It is very important to maximize the interaction between the REU students and their faculty mentors, as well as the communication among the students themselves. This is imperative for their success, especially those who have not had any experience in research before. Another critical aspect is to prepare students for the appropriate research projects. In our case, since not all students have the knowledge in *software safety* required for their research, a series of lectures on this subject are provided during the first two weeks to help students improve their competency. In addition, we also have seminars by guest speakers from industry who have extensive experience in practicing software safety as part of their job responsibilities. The challenge of selecting the right project cannot be overemphasized. Factors such as the scope, the amount of effort required, and tool support should all be considered. It is also essential to maintain a close collaboration with our industry partners. Hence, besides working on assigned research projects on campus, field trips to Raytheon, Lockheed Martin Aeronautics Company, and EDS/HP are arranged to help the students better understand how software safety is adopted in practice for real-life applications. This also gives students a chance to directly communicate with practitioners to receive a first-hand account of the work environments and lifestyles in the industry.

We have observed that many undergraduate students do not have enough experience in writing technical reports and/or delivering technical presentations. Thus, we also help them polish their communication skills. This is very important because no matter how good a researcher's results are, eventually the discovery must be put in a written document or an oral presentation for the rest of the community to reference. A close partnership has been formed with the Writing Center, Office of Student Success and Assessment at UTD to provide training on effective technical communication.

In summary, while working toward a specific research goal, it is also important to help undergraduate students develop a broadly applicable skill set that includes written and oral communication, research methods, critical thinking, and problem solving, from which they can benefit in their future studies.

Junhua Ding
Department of Computer Science
East Carolina University
Greenville, NC 27858

Undergraduate research experiences provide invaluable preparation for students pursuing excellence in their future professional careers and graduate studies. The best strategy for training undergraduate students in research is to offer them the opportunity to engage in real research and interact closely with faculty members.

In many cases, students are also required to make meaningful contributions to their research projects. However, many undergraduate students don't have the basic skills for doing research. The challenges we face in training undergraduate research experiences include developing feasible research projects and building a guiding research environment. For undergraduate students in software engineering, the skills for building high quality software systems are the fundamental requirements for doing related research. But they are not ready to develop useful software systems due to their incomplete training in software engineering. For example, junior students in computer science or software engineering may have no knowledge of software process management so they don't understand process control and improvement. However, process control and improvement are important to the quality of software development. Therefore, students should take topic seminars and workshops of intensive training in software engineering processes, methodologies and tools and develop small software systems before they are allowed to participate in research projects. Common topics offering in seminars should only cover the general principles and the topics should be illustrated mainly by practical examples or case studies. For example, process models can be explained with Rational Unified Process, automated software testing tools can be described using JUnit, and software framework is also possible to be generally discussed using J2EE.

Workshops on special research topics such as security on social network or software testing of cloud computing systems should be also conducted in groups to broaden students' research view and trigger their interests in discovering new solutions. Obviously, the special research topic workshop should be offered mainly for experienced researchers, but it offers participating undergraduate students some research flavors in advance. Students also need to discuss their research interests with faculty members to find their research projects.

Since most undergraduate students who are engaging in software engineering research have to develop software systems, an integrated software development environment (IDE) extended with interactive guidance is important to ensure the success in development. The IDE should be able to be easily set up for enforcing students to develop software systems following a set of predefined software engineering practices, and it should have a way to precisely understand how well a student is applying the software engineering practices so that it can provide specifically guidance to the student. The development activities and results generated in the IDE should be automatically collected and analyzed, and the analysis results can be used for advising the improvement of the research training.

Gene Fiorini
DIMACS
Rutgers University

Prior to participating in a research project, the undergraduate's perspective has been shaped by the "structured" environment of coursework. Students become familiar with conventional, short term goals that have predictable outcomes. This leaves students with unrealistic notions of what constitutes research. Undergraduate research projects and programs are the student's first introduction to a more loosely structured environment where they work on open-ended problems that do not have a clear pathway to a predetermined solution. This presents the first-time undergraduate with some challenges to completing his/her first research project. Mentors are also faced with challenges when mentoring an undergraduate research student. There are competing demands on a mentor's time (scholarship, teaching service, tenure/promotion, etc.) which can distract from providing the student with the appropriate amount of attention. Mentors are expected to teach and supervise students through an initial research project and there is often no format that provides formal training in mentoring. Encouraging and supporting undergraduate participation in research projects involves a number of elements including

- Identifying good research projects,
- Defining expectations,
- Setting benchmarks, and
- Structuring the program for "mentor-student" success.

Good research projects should be reasonable in scope [1]. This will depend on the length of the program and if the mentor and student agree to continue working on the project after the program is complete. Projects should be feasible within the allotted time frame and provide the student with data that can be presented at some future date. Projects should also have some "built-in" difficulties that will become apparent after the student has developed some confidence in their ability to produce a solution to the problem.

With a good research project in hand the mentor could establish clear expectations for the student [2]: What does the mentor expect the student to accomplish while doing research? How independent should the student be? How much assistance does the mentor expect to provide to the student and will that assistance vary as the student gains confidence in his/her ability to complete the project? What do the mentor and undergraduate student hope to gain from the research experience?

Defining a good research project and defining expectations should lead the mentor to establishing benchmarks to accomplish the goals of the project: establish a timeline that is measurable, with multiple "pathways" that promotes reflection on the project. This will encourage the development of new ideas and provide opportunities to learn from false starts and mistakes. Mentors should also consider formative assessment opportunities as well as self-assessment on the part of the student.

Successful outcomes on research projects could also be encourages by taking advantage of resources available at the university. Such resources include leveraging and integrating existing programs, coordinating and sharing resources for recruiting. These resources could also have the additional advantage of broadening participation to underrepresented groups in the STEM subjects.

1. W. E. Wong, "Involving Undergraduates in Research: Motivations and Challenges," in *Proceedings of the 25th IEEE Conference on Software Engineering Education and Training*, pp: 148, Nanjing, China, April 2012

2. "The Path Forward: The Future of Graduate Education in the United States," Report by the Commission on the Future of Graduate Education in the United States, Educational Testing Services and Council of Graduate Schools

Christian K. Hansen
School of Computing and Engineering Sciences
Eastern Washington University

Eastern Washington University (EWU) is a regional comprehensive university and one of six state universities in the state of Washington. Its mission statement "EWU expands opportunities for personal transformation through excellence in learning" is followed by four bullet points that demonstrate how this mission is achieved and the very first of these addresses the importance of undergraduate research:

"Fostering excellence in learning through quality academic programs, undergraduate and graduate student research, and individual student-faculty interaction. Students extend their learning beyond the classroom through extra-curricular programs, life skills development, internship programs, volunteering and service learning."

The university's commitment to undergraduate research is demonstrated by the funding and staffing that is allocated in support of such activities. Since 1998, EWU has hosted an Undergraduate Research and Creative Works Symposium (www.ewu.edu/symposium.xml) now with nearly 500 student presenters and over 100 faculty mentors participating. EWU is also a strong supporter of the National Conference for Undergraduate Research (NCUR). In 2013, 32 EWU students gave presentations with full travel expenses paid for by EWU, more students than any other state university in Washington. Also in 2013, EWU won their bid to host the NCUR in 2015, and has already dedicated several staff positions to begin the work on the planning of this national event.

In the Computing and Engineering Sciences at EWU, undergraduate research and service learning are key components of the required curriculum. For example, senior capstone courses in the Electrical and Mechanical Engineering programs require students to work in teams to solve a real-world problem. Often these projects are supported by internships that in many cases lead to hiring of the student(s) after graduation. Likewise, in the natural sciences many courses have undergraduate research built into the curriculum. For example, in the Fall offering of the course MATH 486: Topics in Advanced Statistics, a required course for B.A. in Mathematics with Statistics Option, every student in the class elected to submit an abstract to present the results of their project at the EWU Research and Creative Works Symposium. With time series analysis being the core theme of the course, students performed individual modeling and analysis of such data as unemployment rates and gasoline prices.

While historically, students were not exposed to research before their graduate education, more recent trends of involving undergraduates in research pose a number of challenges:

1) Undergraduates have limited specialization in their field and require individualized mentoring from a faculty member.
2) Few academic courses teach students the skills of technical writing and the use of library resources.

Overcoming these challenges requires a firm commitment from the institution and its faculty. Adequate staffing must be provided in order to keep class sizes in core senior courses small and funding for students to present at undergraduate research conferences must be provided. Keeping class sizes small is particularly challenging for larger programs/institutions. Finally, faculty must be able and willing to invest the time it takes to mentor and inspire undergraduates to engage in research. To facilitate that, faculty activity plans must be designed such that the criteria for promotion and tenure demonstrate incentives for faculty engagement in research involving undergraduates.