Cultivating Cyberinfrastructure Careers through Student Engagement at Texas A&M University High Performance Research Computing

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ABSTRACT

Texas A&M University High Performance Research Computing (HPRC) has a rich history of fostering cyberinfrastructure (CI) careers by mentoring students. Previous student fellows have gone on to become CI professionals in academia, agencies, or in the commercial sector. The growing need for CI experts is only increasing and we need to build a robust national CI pipeline. At HPRC, students are involved with several aspects of operations, including research-facing systems support, education and training, outreach, application development, and testing novel HPC architecture. Furthermore, HPRC student researchers gain invaluable experience on using CI technologies. Here, students have benefitted from the novel opportunity to work with industry experts on two of the National Science Foundation's composable computing systems. These opportunities have prepared them to adapt to new technologies as they advance in their careers. Here, we share our framework to help other institutions deploy similar student programs.

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1 INTRODUCTION

Texas A&M University's High Performance Research Computing (HPRC) has played an integral role in the university's research mission since 1989. Sitting within the Division of Research, HPRC is closely situated with the research community and operates alongside enterprise information technology. Today, it is emerging as a foundational source in providing research computing resources to scientists across the nation. Within these roles, HPRC has amassed a legacy of student training and development that has led to the launch of an extensive number of careers in cyberinfrastructure (CI) and high-performance computing (HPC). By harnessing undergraduate and graduate student interest through student-led projects, application development, exposure to cutting edge technologies, training, and mentorship, we have developed a culture that promotes the pursuit of career opportunities within this field, including within our organization, other academic institutions, and private entities. The longevity of the success of the student training efforts is demonstrated by the fact that several full-time staff, including two out of three current Directors at HPRC, started their careers as student researchers who worked in CI. The inclusion of students in research utilizing HPC systems has resulted in widespread exposure to potential careers within this field to students from a wide array of backgrounds and has strengthened advocacy for both training and resources in the realm of CI and HPC. This is especially critical now as there is a shortage within the Research Computing and Data (RCD) workforce and HPC centers and organizations struggle to recruit and retain staff [1].

2 METHODS

The framework for student development at HPRC is a multi-faceted model (Figure 1), focusing on cultivating skilled CI researchers and

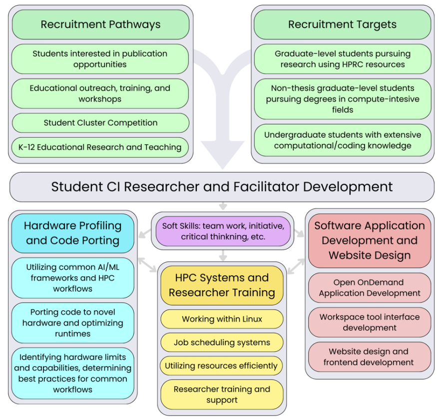

Figure 1: Student development model deployed by Texas A&M High Performance Research Computing.

facilitators in an environment that helps the students foster and pursue their career aspirations. While having its roots in ad hoc hiring of student researchers, today we have a student program with defined learning objectives and outcomes. We describe the various aspects of our student development framework, which include mentoring, research guidance, and job/project-based training. Students initially complete an onboarding process that introduces them to the work they do to support researchers through the help desk. Their supervisor oversees the help desk program and job-based training, and they, alongside the student's peers, mentor them as they work and learn. Other staff members share the oversight for other aspects of the training program. Students contribute to publications under the guidance of various researchers in the HPRC group and more experienced students are given the opportunity to be peer-mentors for new recruits. Thus, these students have opportunities to work with many HPRC staff and research scientists on different types of projects that broaden their experience and help prepare them for the workforce. Herein, we provide the current practices and insights gained from including graduate and undergraduate students in research and operations, as the center has grown to become a national resource provider [2-4]. Our organization has gained a vast amount of experience in working with students at various levels and promoting careers in HPC and RCD. We share our experiences to promote further student participation in HPC and RCD within a university environment to cultivate a supply of flexible professionals for an expanding CI workforce demand.

3 STUDENT RECRUITMENT

Undergraduate and graduate student development requires a significant commitment by members of the HPRC; considerable effort goes into providing the training and resources that ensure students succeed within our organization. As such, careful consideration goes into the student recruitment process. Texas A&M University has a large student population (>74,000) with a broad range of academic pursuits and the user-base for our systems includes faculty and students from many disparate disciplines. This gives us a large pool of candidates to onboard for student researcher and facilitator positions. Given the necessary technical knowledge and skill sets required to perform well within the HPRC, most of our students are recruited from three specific areas (see Figure 1). In order to reach these students, the HPRC pursues various avenues of outreach and engagement, including hosting Student Cluster Competition teams, user workshops and training events, and providing opportunities for students to publish scientific studies.

4 LEARNING OBJECTIVES FOR STUDENTS AT HPRC

Learning objectives and outcomes were developed by our students for themselves in 2017. While initially focused on developing technical computing skills, we have since expanded them. We try to develop soft skills, like learning about workplace culture and etiquette, how to work as an effective member of a team, and how to work with people from different backgrounds (both cultural and technical). We strive to do this by establishing an environment that reflects these ideals and providing both supervisor and peer mentorship. We also train students in technical areas, including working effectively in a Linux environment, understanding HPC scheduling systems (e.g. Slurm), using HPC computing platforms, and employing common artificial intelligence and machine learning frameworks. Students are encouraged to take advantage of courses offered by HPRC. Students also build upon their existing skills through supervised application development and deployment. These skills help students to operate effectively while supporting HPRC and will prepare them to transition into full time roles upon graduation.

5 STUDENT EXPERIENCE AT HPRC

5.1 Student Roles

Research on Cyberinfrastructure- HPRC student fellows have actively published papers since 2019, with the first few papers focused on evaluating educational and training methods [5-9]. Today, HPRC supports several National Science Foundation (NSF)-funded clusters – FASTER, Launch, and ACES [2-4]. The NSF FASTER cluster and the NSF ACES testbed systems represent the first of a generation of computers that leverage composability at the hardware level. These systems provide access to novel technologies, including Graphcore's Intelligence Processing Units, NEC Vector Engines, NextSilicon co-processors, Intel Field Programmable Gate Arrays, Intel Max (formerly Ponte Vecchio) GPUs and other cutting-edge accelerators [2, 3]. Here, students get the incredible opportunity to be some of the first in the world to experience these technologies. The opportunity comes with the responsibility of understanding these cutting-edge technologies, improving usability, porting code and expanding research workflows that can utilize them, and providing users with the best possible documentation. HPRC student fellows, who are typically graduate-level students, actively engage with experts from various academic departments and industry throughout this process. Porting and optimizing code in novel frameworks requires significant work, often without the guidance of previously-established protocols. Being among the first researchers to thoroughly test the capabilities of these new systems, student fellows have also had the opportunity to present and publish their findings at numerous conferences [10-17]. These students play a crucial role in testing many of the systems supported by HPRC, and, in many ways, these students pave the path for researchers to have a seamless experience on the NSF test-bed systems.

Help Desk Services - This role involves being the first point of contact in our ticketing system for customers who need assistance. These requests currently come through an automated management system that generates support tickets from emails and online submission forms. The role of students in researcher-facing support serves multiple functions: it helps alleviate the workload of full-time staff allowing them to focus on other duties, and it allows students to become more familiar with HPC research and the Linux environment. This involves real-time problem-solving, training, and self-education; it is a much different environment than a classroom since it enables the development of professional maturity, accountability, and responsibility.

Application Development and Website Design - Students at HPRC are often interested in developing applications to help researchers in various aspects of research computing (both within and outside of HPRC) or helping HPRC staff with day-to-day operations. Students are encouraged to present ideas to staff with whom they can then collaborate for the development and deployment of their application. Student-led applications that have been developed or are under development include a Slack workspace tool that helps organize and distribute helpdesk tickets and several extensions to our research computing portal [18-20]. Students at HPRC who display a proclivity for website development and design may help update and maintain the HPRC website. This includes creating new pages for training events and workshops and updating our Knowledge Base (KB; publicly available documentation for our system users) with new protocols and instructions.

Researcher Training - Throughout the fall and spring semesters, HPRC offers a variety of training opportunities for researchers across the nation. These include Primers, which are one-hour, online sessions for those who are new to HPC, two-and-a-half hour hands-on short courses, and full-day workshops. Primers cover topics such as introductions to various systems, working in the Linux environment, and data management. They are taught by students and take place within the first few weeks of each semester. To prepare for teaching these hour-long sessions, students are expected to go through all the presentation slides and to complete all of the exercises so they can guide the participants through them and answer questions. The students will rehearse teaching the material to other student fellows and to one of the staff members, who will give them feedback on materials, pacing, and engaging participants. The benefits of having students teach these training sessions are twofold: 1) students must become proficient in the tasks/workflows they are teaching, ensuring they are well-trained on our systems; and 2) it gives the students the opportunity to practice and develop public speaking and engagement skills. Soft skills garnered through this process are highly transferable and will help once they enter the workforce. Students also assist with short courses taught by full-time staff and help answer questions and trouble-shoot any issues encountered by the trainees. This helps the presenter keep the flow of the presentation while meeting the needs of the participants by addressing their questions. Students are also asked to review presentation slides and test the coding examples to ensure that they work well on the cluster being used, especially when they are revised for a new cluster. This provides them with a better understanding of the types of research being conducted on our systems and will prepare them to answer help desk questions.

School Student Summer Camps - HPRC organizes the Summer Computing Academy camps for middle and high school students. Every year we offer two to three weeklong camps that collectively support over one hundred K-12 students. During these camps, HPRC fellows prepare classroom instructional materials, act as counselors, and often develop and teach materials. Other summer camp duties for HPRC students include mentoring our campers, logistics support, and ensuring camper safety. HPRC fellows that participate in the camps, especially those taking on more educational roles, benefit from gaining experience teaching and engaging others interested in computing, as well as experience the organizational and logistical support required to host these types of events.

5.2 Student Orientation and Preparation

The successful student experience requires that students understand the technical needs of these positions. On the student's first day at HPRC, the supervisor covers any general information required, including introductions to other students/staff/researchers, work etiquette, responsibilities, and expectations. Students are also given access to documentation that covers all this information. This orientation is critical for defining responsibilities and ensuring that expectations are clearly communicated. Following this discussion,

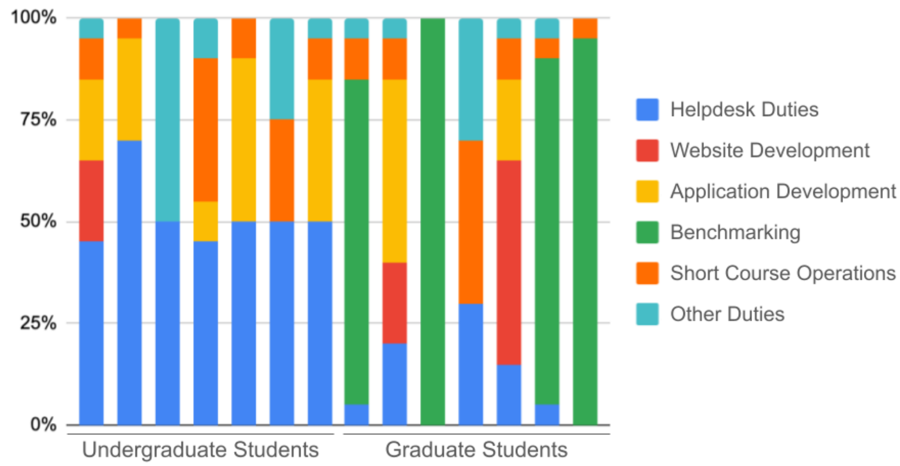

Figure 2: Breakdown of current student roles/responsibilities at Texas A&M University High Performance Research Computing. Each column represents the responsibilities of a single student.

students are granted access to various organizational systems and software (e.g. Slack, Request Tracker, GitHub) and given accounts on our clusters. This process acquaints students with account-generation and the steps users must take to gain access to our systems, which, in turn, will help them support new users in the future. Once the student has access to all the organizational systems and understands the expectations and standards of internal and external communication, they are asked to review our KB and internal documentation that covers best practices and standard operating procedures. Once the students have a solid understanding of our documentation and how to operate on our systems, they will begin to help answer user questions and tickets.

5.3 Student Responsibilities and Expectations

Students are held to the same professional standards as full-time HPRC staff and researchers; they perform complex activities and bring innovative ideas to our organization. While students do not have the same level of responsibility as staff, as a group, our students fill a gap in outreach as peer-mentors and problem solvers, which enables staff and researchers to focus on advanced projects. This includes handling standard user questions and support requests or ensuring more advanced tickets (e.g. requiring discipline-specific knowledge) are funneled to the correct staff/scientists. Students are given sufficient flexibility in their schedules to accommodate academic obligations; students are allowed time off to prepare for examinations, participate in job interviews, and explore internships. Schedules and hours are monitored through a shared online spreadsheet, which keeps them accountable and ensures that we are apprised of student availability. Students spend up to 20 hours a week on HPRC duties, typically spread over 4-5 days. The responsibilities and assignments of each student vary and are frequently aligned with the student's areas of interest (Figure 2). Students tasked with research on CI or application development are expected to keep detailed notes in a shared space that is visible by everyone in the organization. This helps keep students on track and allows staff to intervene when issues arise.

6 STUDENT GROWTH OPPORTUNITIES

6.1 Mentoring

Student mentoring and preparation is an inherent part of the HPRC team dynamic. When new student fellows join HPRC, the supervisor assigns multiple peer mentors who help them learn general procedures, systems used at HPRC (such as Request Tracker for tickets, Google Drive, Github, and Jira), help desk culture, and ticket handling. The supervisor regularly meets with new student workers to make sure there are no areas of concern or to cover any aspects that might need clarification. New students are encouraged to review tickets and discuss with other students and supervisors how they should respond. The supervisor will provide feedback and suggestions until they are ready to respond independently. Once new students are trained, the supervisor gets them involved with additional projects (e.g., YouTube processing, frontend/backend development, application development) based on student preferences and strengths. HPRC strives to provide enough redundancy so that multiple students are involved in every project. This fosters team cohesion with more experienced students mentoring newer team members who work on the same projects.

6.2 Participation in the Student Hiring Process

Student positions at Texas A&M HPRC are highly coveted; for example, each advertised position for a graduate student researcher typically receives more than 60 applications. The student researcher hiring process is well defined. During the hiring process, we conduct in-person interviews. The interview committee typically includes a senior researcher, a junior researcher and at least two incumbent student employees. This experience acquaints current students with the hiring process from the perspective of the employer which will prepare them to interview for positions upon graduation. It also allows students to share their HPRC work experience with the interviewee and answer questions regarding the day-to-day workplace culture. Since our students often operate as a unit, maintaining the team dynamic is critical. Students are an integral part of the hiring process because they will provide feedback on how they think the interviewee will contribute to the team.

6.3 Presentations and Publications

Students are encouraged to present their work at conferences, such as the annual PEARC (Practice & Experience in Advanced Research Computing) and Supercomputing conferences and may author or contribute papers or posters. These efforts have benefitted our students in several ways. First, several of our graduate students are non-thesis, and this might represent the only opportunity they have to generate publications during their graduate experience. Second, it strengthens the student's confidence, public speaking ability, and project management skills; all of which will help as they enter the workforce. Several of our students have appeared on local news or in regional academic publications. Lastly, attending conferences broadens their knowledge of available CI career opportunities in academia, government agencies, and industry. It also helps them network with organizations they might apply to after graduation. Most conferences have student programs and career fairs to guide them through the process.

6.4 Engaging Underserved Communities

Interested student employees may participate in a variety of such programs at HPRC. Students have been actively involved in the NSF-funded BRICCs program (Building Research Innovation at Community Colleges), which promotes access, awareness, and utilization of advanced CI resources at community colleges and under-resourced four-year institutions [21-23]. Students are also given the opportunity to participate in our K-12 outreach programs [24, 25], working closely with children from across the nation to foster interest in data science and cybersecurity. Such opportunities allow HPRC student fellows to experience STEM (Science, Technology, Engineering, and Math) education and outreach, an area that will help serve national interests in future research, particularly CI [26].

6.5 Student Career Paths

After graduating, HPRC students often pursue careers in HPC research or support, or as lead software developers or engineers. These include applying for full-time positions with HPRC, positions at other academic institutions, or careers working with advanced CI in industry. Students have continued to work as full-time employees at Texas A&M University HPRC. Indeed, the NSF SWEETER CyberTeam at one point employed five full-time employees who were previously students. Today, alum work at academic research computing centers and industry partners including Google Cloud, Sonos, Dell EMC, Facebook, Microsoft, Roku, Amazon, Capital One, Great Bear A/I, HEB Information Technology Services, and municipal Information Technology services.

7 CONCLUSIONS

Student engagement is an important aspect of HPRC operations. Our student program helps promote the education and research missions of our university, the Association of Computing Machinery, private industries and government agencies. Our debut as a national resource provider [2-4] will likely lead to further refinement and expansion of our student program. An emphasis on scalability leaves us well-situated to make these advances with ease. Furthermore, this expansion will allow us to have even more success in the development and training of the federated CI workforce. This scalability also allows for easy adoption of our approach at smaller institutions. Integrating student employees in existing workflows, especially in areas where full-time staff might be stretched, is the quickest way to onboard students. As students develop, they can begin to assume additional responsibilities or projects within their areas of interest and expertise that will further engage them and expand the capabilities and outreach initiatives of the hiring center.

Another way HPRC excels is our constant development and delivery of training opportunities for local, regional, and national stakeholders. The HPRC group offered more than 80 hours of live training in the 2023 fall semester, not including our workshops and conference tutorials. Our students were heavily involved in these efforts and are no small part of our success. This experience contributed to their development, in regard to both the primer material they were tasked with teaching, and the more discipline-specific topics they helped develop and test; the latter of which provided increased insight into the types of research conducted on HPC systems outside of their areas of study.

The inclusion of students at the level described in this paper requires a major commitment of time and money. However, the benefits vastly outweigh the investment. We offer a blueprint that other institutions may adopt, or incorporate aspects thereof, for their operations. Along with the methods described in this paper, HPC centers can employs other avenues for student engagement and CI workforce development, including: HPC-related hackathons [27], long-form workshops [28], incorporating HPC curricula in undergraduate and graduate programs [29-31], and Student Cluster Competition team facilitation [31-32]. All these activities help drive student engagement with HPC. We believe that if all campus HPC providers learn from our experience, the global CI workforce will be better prepared for a future that addresses HPC's expanding role in our lives.

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