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CUR Focus

Morna Brothers, Thomas Higgins,
Harold Washington College

Research Models that Engage Community College Students

Our vision is to tap the rich and diverse community college student body to produce the future workforce this nation needs in science, technology, engineering, and mathematics. Community colleges annually enroll almost half of the nation's undergraduates and collectively educate its most diverse student body with respect to race, age, and economic status. According to a 2004 National Science Foundation (NSF) Infobrief, more than 40% of recent science and engineering graduates attended a community college at some point during their academic career. In addition, these institutions provide the primary science education for a substantial number of the nation's K-12 teachers, both pre- and in-service. Clearly community colleges play an important role in the education and training of young scientists.

To realize this vision, a network of 13 Midwestern colleges and universities have come together to form the STEM-ENGINES (ENGINES stands for Engaging the Next Generation IN Exploring STEM). Of these institutions, 10 are community colleges in the Chicago metro area (the seven City Colleges of Chicago, along with William Rainey Harper College, Oakton Community College, and the College of DuPage), which collectively educate over 100,000 students annually. Three are baccalaureate-granting institutions—Illinois State University, Hope College, and Youngstown State University. For the past two years, this collaborative has been exploring three questions: How can research encourage more community college students to study science? What factors encourage these students to pursue STEM careers? How do we best put these ideas into practice?

Program Overview

This program emerged from conversations among a group of chemistry faculty members from three Chicago-area community colleges with a passion for their students' success and a desire to reconnect with their discipline. By networking with colleagues at baccalaureate-granting institutions and with initial funding from the NSF in the form of a Small Grant for Exploratory Research, three core ideas emerged that eventually became the organizing principles for the STEM-ENGINES:

(1) *Real research questions* must challenge students and allow them to fully contribute to production of new knowledge;

(2) *A scholarly community* must support students as they grow as both scientists and citizens; and

(3) *Student transitions* beyond the community college are key to students' long-term academic success and engagement with STEM as a career.

STEM-ENGINES is primarily funded under the National Science Foundation's Undergraduate Research Collaborative (URC) program (CHE-0629174). At this time, we are beginning the third year of a five-year, $2.7 million dollar grant, which is supplemented by funding and other support by each campus. During the first two years, 116 students benefited from our program, which is organized around recruiting community college students with an aptitude and interest in science and, using undergraduate research as the hook, engaging them in the process of exploring the natural world and producing new knowledge.

Our recruiting efforts cast a wide net, snaring the best and the brightest as well as the diamonds in the rough—students who may not be strong academically but have tremendous intellectual promise. We aim to broaden our students' "visions of the possible" by demonstrating that science is an enjoyable and accessible field for anyone with a curious mind and a strong work ethic—that it is not solely the providence of the gifted.

Working with a faculty mentor, each student pursues an independent research project on his or her home campus during the academic year. Students receive both a modest stipend and academic credit for a research course, alleviating their need to work outside of school and recording the research on their transcripts. The research experience is supplemented by explicit soft-skill development in areas such as time-management, laboratory safety, and exposure to professional literature.

We also concentrate on building scholarly communities, bringing together students, faculty, administrators, and visiting scientists from all of the STEM-ENGINES institutions to create an environment in which students can learn and talk about science. At the end of each semester, all students present their research at an in-house poster session, which allows students to practice their public-speaking skills and encourages them to present their work in public venues such as regional and national meetings.

A secondary goal is to build a solid pipeline from our community colleges to baccalaureate-granting institutions with a genuine interest in our students' success. We engage institutions that will encourage our students to continue in undergraduate research and will support them during the often-difficult period of inter-institutional transition. Towards this end, students are encouraged to seek full-time, off-campus summer research internships. Our baccalaureate partners offer opportunities similar to a traditional Research Experience for Undergraduates (REU) program, providing a stipend and housing. (Each summer, 14 such positions are funded by our grant.) Getting off campus allows students not only to immerse themselves in science and research, but also to explore a new environment and make new friends. Many of our students are also successful at acquiring internships outside of the URC, sometimes at future transfer institutions. To ease the transfer shock to a new environment, we provide limited travel grants that enable students to visit summer host campuses and meet summer mentors prior to the end of the academic year. We have found these bridge-building experiences are critical for overcoming students' trepidations about leaving home, thus ensuring that students have productive and stimulating summer experiences in unfamiliar environments.

Models of Undergraduate Research

The core of the STEM-ENGINES program is the student's undergraduate-research experience. Ideally, a student will pursue research on his or her home campus beginning in the fall semester under the supervision of a community college faculty mentor and transition to an REU or similar program at a baccalaureate-granting institution during the summer.

One thing we have consciously avoided, however, is trying to impose a single model of research on all of our collaborating institutions. Instead, we have built a community around the common theme of *creating student successes through research*, leaving the details of each program's implementation to the individual campus. Following this philosophy, four models of research have emerged:

(1) A "traditional" student-mentor model, utilized by faculty members at Harper College (HC) and the College of DuPage (COD). This is an academic-year program in which each student pursues his or her own research project, working closely with a single faculty mentor. Students pursue their research in addition to taking a full course load and often get credit for their research through independent study courses. At both campuses, the research is supervised by individual chemistry faculty members. Many students at COD spend their summer at Argonne National Labs in the NSF-supported Faculty and Student Teams (FaST) program.

(2) A "course-based" model, developed at Oakton Community College (OCC). This is an academic-year program in which students formally register for an interdisciplinary research course simultaneously taught by up to five faculty members. Course enrollments are small (six to ten students), ensuring each student receives a considerable amount of individual attention. At the beginning of the semester, faculty members present a variety of research options, and students collectively decide which to pursue and develop a plan for achieving the class's research goals. Within the context of these common goals, each student takes ownership of a specific aspect, becoming the local expert and assuming responsibility for instructing his or her peers. Another feature of this model is that many projects involve significant interaction with the local community, and collaborative projects with Argonne National Labs and the Chicago Botanical Gardens have been pursued. The OCC faculty members involved in the project represent chemistry, biology, biotechnology, and medical technology.

(3) A "multi-institutional" model, developed at the seven City Colleges of Chicago (CCC). This model incorporates aspects of both the models described above, with three to five students at a single campus working closely on a common project with two to three faculty mentors. Students get credit for their research though a series of independent research courses developed specifically for this program. The CCC faculty members involved are primarily from chemistry, biology, and biotechnology. Each campus is encouraged to develop interdisciplinary projects. Each month, all seven CCCs come together under the umbrella of the Center for Science Success (CSS), a district-wide community that provides a forum in which students can meet their peers and talk about their science. At CSS

meetings, students are expected to meet with visiting scientists from the community, lead discussions on journal articles, and present their own research roadblocks and accomplishments—much like students would in a journal club in graduate school.

(4) An "REU" model, in which community college students are integrated into the existing undergraduate-research community of our baccalaureate-granting partners. This is primarily a summer program, where students are expected to devote their full time and attention to research. This is an opportunity for students to sample life at another institution, which is significant considering that many of the STEM-ENGINES students have never traveled far outside of the Chicago-metro area. It also allows students to meet a new group of students and faculty members, expanding their personal scientific network. Finally, students also have the opportunity to work with dedicated-research instrumentation, something community college budgets rarely allow.

Nature of Research

One of the questions we most often face is, "Can community college students do 'real' research?" The answer is a resounding, "Yes!"

We consider "real" research to be projects that engage students in the production of new scientific knowledge and that advance a discipline. Reasonable litmus tests are whether the results of the research will be suitable for publication in a peer-reviewed journal, produce a patent, or lead to the submission of a research proposal. Indeed, the authenticity of the research project is of utmost importance to the STEM-ENGINES. Any research project for which the results are already known is not going to engage students' interests for very long and actually works against the goal of using research as a method of recruiting promising community college undergraduates into the sciences.

Some of the student research "deliverables" produced through this project include three peer-reviewed publications (one published with two accepted and pending publication), a patent submission with scientists from Argonne National Labs, and 17 poster presentations in forums such as the Notre Dame REU Summer Research Symposium, the Chicago Area Undergraduate Research Symposium, and the Argonne Symposium for Undergraduates in Science, Engineering, and Mathematics. Some of our students also have won prestigious and financially lucrative awards and scholarships, such as the American Chemical Society Scholar award and the Jack Kent Cooke Scholarship.

Resources Required

Time is, of course, the most precious resource for both students and faculty members, and creating the time for research is essential. In order to have a meaningful and educational experience, students need to balance the research expectations of their projects and their mentors with the demands of their courses and other responsibilities. These responsibilities often include caring for children (many of our students are single parents) or parents, and the need to work to earn money to pay for their education and living expenses. To support students, we pay them a modest stipend during the academic year and also enroll them in a two- or three-credit research course whenever possible. (Tuition and fees are paid by the institution in addition to the students' stipend.) This does two important things: The stipend alleviates students' need to work outside of college, and the credit hours help students achieve full-time status. This is important because the City Colleges of Chicago provides all full-time students with a "U-Pass," which allows free public transportation during the academic year. Without the U-Pass, students would pay $75 a month for transportation.

For the faculty mentors, creating the time to mentor students is the most pressing challenge. Traditionally, community colleges have concentrated their resources on providing high-quality, classroom-based instruction. Therefore, faulty have high teaching loads (15 contact hours per semester is common) and, with the intense student demand for science classes, many teach overtime (3-6 contact hours of overtime each semester is not uncommon). In addition, community colleges rely on a substantial number of adjunct/contingent faculty members, meaning a full-time faculty member relieved of classroom teaching duties may not be replaced. In general, there have been three institutional solutions to this, which are mixed-and-matched as the demands of enrollment dictate:

(1) Faculty members are given release or reassigned time, reducing their teaching load. This usually means a faculty member has to mentor a minimum of two students per

Anthony Isom, Jr., at work in a Truman College lab.

semester and play an active administrative role on his or her campus in supporting the URC grant.

(2) Faculty members are given overtime pay in proportion to the number of students mentored.

(3) The research courses in which students enroll are counted towards a faculty member's load or overtime.

At an institutional level, there is the additional challenge of building and maintaining research facilities, which can be quite expensive. Since most community colleges rely on primarily local and state taxes for funding, even modest research budgets are not realistic. To overcome these difficulties, partnering is crucial. Partners provide access to essential resources such as equipment and instrumentation, library references, and human knowledge and expertise. With our partnerships, we have been able to share training and use of instrumentation that would never have been available to our institutions outside of collaboration.

Observations and Assessment

We have observed the following while putting our ideas into practice and meeting the challenges that have arisen:

(1) Despite receiving stipends, students still need to supplement their income with other employment. While this is best accomplished with an additional on-campus job, this is not always possible.

(2) Academic-year internships with close faculty mentorships are key to helping students grow as researchers and gain the confidence they need to consider leaving home for the summer and pursuing careers in science. Through their research, students become more comfortable and knowledgeable about how science is done and its inherent uncertainties.

(3) Seasoned students should be encouraged to take on mentoring and leadership roles, thereby becoming even more engaged, as well as contributing to their own personal development.

(4) Although we had originally envisioned monthly meetings among all URC institutions, in practice the larger community has been strengthened by decreasing the number of large meetings to twice a semester. In addition, encouraging smaller groups to meet on their own schedules has created multiple support groups.

(5) Student transitions are best supported with a friendly face and a familiar environment. The willingness of faculty members from our baccalaureate partners to travel to Chicago and meet with our students, as well as our student travel grants, have been crucial to encouraging our students to pursue summer REU opportunities. These factors also have increased students' awareness of potential transfer institutions.

(6) Because many of our students have employment and/or childcare obligations in Chicago, they are not able to leave home for the summer. In order to meet the needs of these students, we will need to increase the number of local internships.

Our assessment efforts are concentrated in three areas:

(1) Tracking students' successful completion within the STEM-ENGINES academic year program. Successful completion requires meeting their faculty mentors' expectations, which at a minimum include devoting nine hours a week to their research, presenting their research at meetings, and applying for summer research opportunities. Success is reflected in the grade received in the independent research course; students must earn a B or higher to continue their participation. Those students who do not meet this criterion are not invited to return nor are they recommended for summer research positions.

(2) Tracking students who transfer from community colleges and pursue science majors. This may be the most difficult aspect of our assessment effort, as once students leave the campus, they can seemingly evaporate. Luckily, we are able to maintain contact with many of our students, at least for the first year after they leave our campus. We attribute

this in part to the strong sense of community built into the STEM-ENGINES program.

(3) Measuring students' development as scientists and scholars. For this, we are using the Survey of Undergraduate Research Experience (SURE) instrument developed by David Lopatto at Grinnell College. Some of our preliminary SURE data are discussed below.

With respect to student tracking, 116 students were accepted into the STEM-ENGINES during the first two years of our program; 105 students (91 percent) completed the academic-year portion of the program, and 63 of those (54 percent) went on to summer internships. 40 of our students (34 percent) have transferred to baccalaureate-granting institutions. During the second year, 18 students out of the original cohort of 63 (29 percent) returned to the program. The 11 students (9 percent) who were unable to complete the program had a variety of reasons for leaving, including personal and/or family problems, deciding to enter the workforce, and finding the research too rigorous. Our students tend to have important commitments outside of school, and not all who apply are ready or able to dedicate themselves to the time required to conduct research.

From the results of the SURE survey, which measures student perceptions before and after the research experience, we have noticed three important trends:

(1) Our students self-report learning gains in the 21 domains measured that are equal to or greater than the national average. The control population largely consists of students from baccalaureate-granting institutions, most of whom are juniors and seniors.

(2) Upon completion of a summer research experience, the number of students who intend to pursue a graduate degree in STEM increases by 31 percentage points, from 44 percent before to 75 percent afterward.

(3) The number of students who are not considering attending graduate school drops from 11 percent before to 3 percent after the experience.

Conclusions

Our undergraduate-research collaborative is dedicated to engaging community college students in scientific research, and increasing the number and diversity of students earning science degrees. As our program begins its third year, we are focused on creating a positive environment for research, understanding the effect undergraduate research has on students' decisions to pursue science, and providing a research model for other community colleges to follow.

Most importantly, our students have demonstrated through their hard work and research products that community college students can make a meaningful contribution to both the current body of scientific knowledge and the growing need for a larger and more diverse professional scientific workforce. We are striving to promote student successes by analyzing the program and identifying strengths and challenges. A number of themes have emerged, among them: all participants require time and space to do research; different populations have different needs, which will drive the programming; and our scholarly community flourishes with variety in teaching models and resources.

In the program's third year, we need to assess what kind of long-term impact the undergraduate research experience is having on students' decisions concerning future study and career. Specifically, are students' choices influenced by early research experiences? This demands a complex approach. While we will continue to administer assessment measures and track students as they leave the program, we face certain challenges. One difficulty is establishing a base-line control group against which to compare our students. A culture of research at community colleges is newly being established, and there are only a few similar programs of which we are aware. Another challenge is the small sample size of our student cohorts, which makes it difficult to determine what aspects of the research program have the strongest effect. As the program continues, and our student cohort grows, we expect to be able to look at these factors in greater depth.

With three years of funding remaining, we are leveraging our students' successes to institutionalize and sustain the program as well as provide more research opportunities for our students, including growing the number of summer internships available in the Chicago-land area. To disseminate our findings and to expand attention of the STEM- ENGINES models, we have begun to record our lessons in a guide that will be able to help other community colleges initiate undergraduate-research programs.

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References

American Association of Community Colleges. American Association of Community Colleges—CC Stats Home. Available at: http://www2.aacc.nche.edu/research/index.htm. Accessed August 14, 2008.

Lopatto, D. Survey of undergraduate research experiences (SURE): First findings. *Cell Biology Education – A Journal of Life Science Education* [serial online]. 2004; 3: 270-277. Available from CBE – Life Sciences Education [database online] at: http://www.lifescied.org/. Accessed August 14, 2008.

Lopatto, D. What undergraduate research can tell us about research on learning. 2004. Available from Project Kaleidoscope [database online] at: http://www.pkal.org/. Accessed August 14, 2008.

Patton, M. In: Barnett L &San Felice F, eds. *Teaching by Choice: Community College Science and Mathematics Preparation of K-12 Teachers*. Washington, DC: Community College Press; 2005.

Tsapogas, J. The role of community colleges in the education of recent science and engineering graduates. *Science Resource Statistics Info Brief* [serial online]. April 2004; NSF 04-315. Available from National Science Foundation [database online] at: http://www.nsf.gov/statistics/infbrief/nsf04315/. Accessed August 14, 2008.

Morna Brothers
Harold Washington College
30 East Lake Street, Room 909
Chicago, IL 60601
Tel: (312) 553-3149
Fax: (312) 553-5786
E-mail: mbrothers@ccc.edu

Morna Brothers is the project director for the STEM-ENGINES Undergraduate Research Collaborative. She graduated summa cum laude with a BA from DePaul University and earned an MA from Indiana University.

Thomas Higgins
Harold Washington College
30 East Lake Street, Room 903
Chicago, IL 60601
Tel: (312) 553-5791
Fax: (312) 553-5786
E-mail: tbhiggins@ccc.edu

Thomas Higgins is a professor of chemistry at Harold Washington College, one of the City Colleges of Chicago (CCC). He is the principal investigator of the URC grant that funds the STEM-ENGINES and the co-leader of the CCC undergraduate-research program. He earned a BA with honors in chemistry from Kalamazoo College and an MS and a PhD from Northwestern University. His current research interests include the synthesis of nanomaterials and their effects on aquatic ecosystems. He is currently a principal or co-principal investigator on two other NSF grants.