LaRoy S.E. Brandt, *Truman State University*
Jack Lee Hayes, *State Fair Community College*

CUR Focus

Broader Impacts of Undergraduate Research at a Community College: Opening Doors to New Ideas

Community colleges are in a strategic position to offer students opportunities that they might not otherwise have had. Many community-college students choose their institutions because community colleges offer them a local opportunity to pursue their education at a more affordable cost and in smaller class sizes than is typical at a four-year public institution. However, developing an undergraduate research program in this environment can be difficult for a multitude of reasons, with lack of financial support from the institution or other sources and the short-term, transient nature of the student population being two of the most prominent drawbacks.

State Fair Community College (SFCC) in Sedalia, Missouri, is no exception, as the institution serves a strongly rural, 14-county area; many of its students use the college to launch their postsecondary careers. And yet, a single undergraduate who was determined to conduct a particular independent research project helped spark an interdisciplinary collaboration that ultimately resulted in new curricula that offer SFCC students a chance to conduct scientific research.

Demographics at State Fair Community College

SFCC is a comprehensive public two-year postsecondary institution that offers programs leading to certificates, associate of arts degrees, and associate of applied science degrees in 23 disciplines. Typical annual enrollment is approximately 3,500 students. On average, more than 51 percent of the student body is made up of part-time students, with an overall average age of 26. Nearly 89 percent of our students receive financial aid; about 50 percent are economically disadvantaged. Approximately 80 percent are first-generation students who work full-time jobs while pursuing their education; 79 percent of our students also require developmental coursework before taking any courses that can be applied toward a degree. Consequently, many of them are ill-prepared to take a postsecondary-level introductory science course.

Approximately 250 to 300 students per year enroll in and complete our science courses that include a laboratory (class size is typically 20 to 24 students). Of those students, approximately 225 to 275 are non-science majors taking an Introduction to Biology, Introduction to Chemistry, or Introduction to Earth Science course to fulfill their general-education requirements. Better than 75 percent of the non-majors transfer to the University of Central Missouri, a four-year institution 30 miles west of SFCC, while our science majors transfer to various four-year institutions throughout Missouri. The non-science majors taking science lab courses are dominated (approximately 35 percent) by students majoring in elementary education, who are required to take two laboratory science courses. The second largest group (approximately 30 percent) consists of students interested in entering our vocational health programs (e.g., nursing, dental hygiene, and radiology). The remaining 35 percent of non-science majors are studying other disciplines (e.g., art, history, sociology, psychology, criminal justice, etc.).

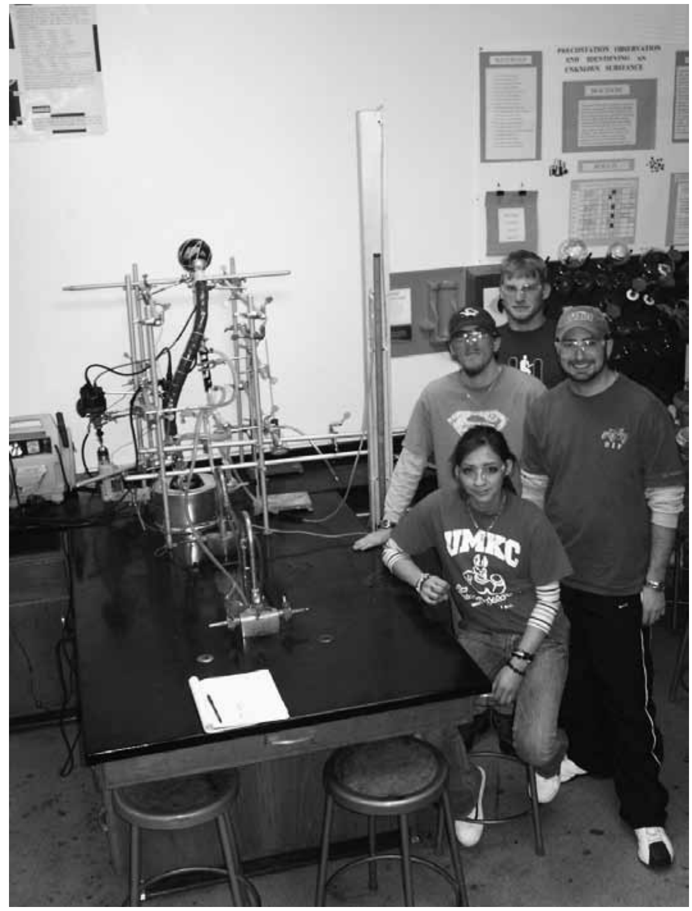
Approximately 25 students per year are science majors expecting to fulfill their freshman- and sophomore-level science coursework at our institution. Within the science majors, most students intend to pursue careers in one of the health professions, followed by conservation/environmental professions, and teaching secondary mathematics and science. While a few others intend on pursuing advanced degrees in pharmacy or various biological fields, an even smaller number of students intend to pursue degrees in chemistry, engineering, or physics. As noted above, a large portion of the students who attend SFCC work full time and many others work at least part time outside of the college.

In terms of the financial situation at SFCC, the institution is very much like other small, state-supported colleges; it has limited resources and few or no dollars to support the additional costs that often accompany undergraduate research. Even if money were available, much like other community colleges, the high teaching loads allow faculty members little time and opportunity to pursue external funding. Consequently, any additional costs to implement and conduct undergraduate research must be absorbed within departments' annual budgets

In spite of all these limitations, a single, student-initiated undergraduate research project inspired the SFCC faculty to embrace undergraduate research through the development of new curricula and integration of student research in both chemistry and biology courses, providing students opportunities to conduct semester-long research projects as part of their normal coursework. The initial project stemmed from a pharmacy student concurrently enrolled in the first-semester biology and first-semester chemistry courses. Her persistence and strong desire to pursue an undergraduate research project (by replicating the 1953 experiments of Stanley Miller and Harold Urey on the "pre-life" evolution of the molecular building blocks of complex biological molecules that are required for life to exist, Miller 1953; Miller & Urey 1959) were all she needed to nudge her professors into a long-lasting, cross-disciplinary collaboration focused on integrating student-initiated research projects into the undergraduate science curriculum. Not only was this initial project successful in meeting its objective, it also led students and faculty alike to realize that high-quality research projects can be accomplished at small rural colleges with little or no research budget.

Although the student-led replication of such a historically important experiment provided innumerable opportunities for all students participating in the project to learn basic biochemistry and provide context for the scientific process, the "real" success was observed by watching a group of students from various disciplines come together in an authentic collaboration using teamwork to solve problems. As this original student project developed, additional interest became apparent from other students, and under faculty recommendation a small student research group developed to tackle the project. This student-led research group was able to take advantage of individual strengths and minimize their weaknesses as they built their experimental apparatus with minimal expenditure. From building their own manometer to measure atmospheric pressure within their reaction chamber to utilizing an automobile distributor, a car battery, and an electric hand-drill to generate the regularly occurring spark necessary for their experiment, the students overcame their anxiety about doing scientific research and realized that what they once felt was beyond their reach was definitely attainable. Moreover, this group of students' attention to detail enabled them to recognize the potential for obtaining a false positive during the first run of their experiment and subsequently led to modifications to their experiment that eliminated their false positive and subsequently produced a legitimate positive result. Ultimately, the success of this undergraduate research project resulted in an increase in student independence, responsibility, and self-motivation, evident in the students' request to present their research at the annual Missouri Academy of Science Conference.

Motivated by this successful UR experience, the SFCC biology and chemistry faculty seized an opportunity to modify the current curricula in the first-year sequence of biology and chemistry courses by integrating significant cross-discipline research components into the respective coursework. Over the course of three years, the curricula of biology and chemistry courses for both science and non-science majors were modified to place less of a priority on content knowledge and more of an emphasis on the real-world, collaborative effort of scientific investigation. Specifically, the focus was shifted to how we know what we know, and not just what we know. Such an undertaking included the first-year sequence of courses for science majors, Chemistry I & II and Biology I & II (courses with typical enrollments of 15 to 20 students each); the non-majors' Introduction to Chemistry and Introduction to Biology courses (typical enrollment of 24 students per section with three to five sections offered each semester); and a new two-semester Introduction to Biotechnology sequence (with a typical enrollment of 10 students in one section each semester).



First-year biology and chemistry students (front to back) Ana Dale, Adam Friese, Bryan Fisher, and Daniel Meenen with their apparatus to replicate the 1953 Miller-Urey experiments investigating the prebiotic synthesis of biological monomers.

The shift from "content-driven" curricula to "process-driven" curricula was initially difficult, as on the surface faculty feared that the change in priority could and would lead to the loss of content learning. However, faculty quickly recognized that objectives for students' content knowledge could still be met by placing a greater expectation of content knowledge on the students as they pursued the research projects integrated into their coursework. Ultimately, these changes enabled faculty members to make more authentic assessments of student performance based on their content knowledge as demonstrated through hands-on application of course material. For example, students in the introductory chemistry course were expected to "silver" a bottle for one of their course exams. The assignment required stu-

Second-year pre-med student Dipendra Thapaliya transfers DNA samples in an effort to determine if electrophoresis could be used to verify the results from the Meselson-Stahl experiments on semi-conservative DNA replication.

dents to work collaboratively in small groups to identify an appropriate procedure, make appropriate calculations, and perform standard lab procedures by mixing solutions prior to each of them performing the procedure independently. If the procedure they used was not appropriate, errors in calculations or errors in the preparation of solutions were made, with the results of the errors clearly visible on the bottle produced. Additionally, having an interesting, new display item created by each student gave the students ownership of their learning that led to deeper appreciation of science in general.

In another example, in one of the new introductory biotechnology courses the midterm exam required students to work collaboratively in small groups to develop a procedure to identify and quantify the individual constituents in an unknown solution of biological molecules. Over the course of one week, the students had to determine appropriate procedures, explain why they chose these procedures, assign various tasks to each member of the team, identify the particular components of the solution, produce appropriate standard curves to aid them in quantification of substances, and generate a final group report of their results. Students not only had to demonstrate their knowledge and lab skills but also their ability to function in the dynamic, collaborative process of science.

With such a change in focus to emphasize the scientific process, the improvements in students' understanding of experimental science and the scientific method anticipated by the faculty became readily apparent as students enrolled in and completed sequential science courses. As students progressed through their biology and chemistry sequences, they began to recognize their own abilities to seek out the information they felt was necessary to understand and complete the experiments they were attempting. Furthermore, students began to ask deeper, more thoughtful questions in pursuit of knowledge beyond what was expected in the course outcomes. In effect, they were becoming scientists. What more could we ask for? Unexpectedly, this question was answered because these students began to seek out additional research opportunities. For example, a group of biology and chemistry students who were all enrolled in the second-semester biology and chemistry courses in those disciplines' curricula asked to conduct a research project monitoring water quality in the local community. With support of the Missouri Stream Team Program, these students collaborated to assess water quality in the entire watershed in which SFCC is located. Their efforts established a long-term, community water-quality monitoring program in which many students still participate.

Other inspired students chose to continue the "replication of historical research" approach that initiated undergraduate research at SFCC originally. After learning of the 1958 Meselson-Stahl experiments, which established our understanding of how DNA is replicated, a student inquired about the possibility of replicating this important work. Stimulated by this request, another pair of students was curious about replicating the 1952 Hershey-Chase experiments identifying DNA as the molecule of inheritance. Both of these experiments presented hurdles the students needed to overcome: The Meselson-Stahl experiments required a high-speed centrifuge, which was not available, and the Hershey-Chase experiments required radioactive isotopes whose use was not feasible logistically. The students in both of these projects sat down together and came up with a solution that benefited all of them by utilizing stable isotopes and modern electrophoresis techniques to separate chemical products by their mass. This minimized the cost of each project and led the students to successfully replicate the original research using modern techniques. Yet another group of students was inspired by the historical extraction of salicylic acid from willow trees and attempted to make such an extraction and convert it to aspirin. Although unsuccessful, their attempt at synthesizing aspirin inspired another group of students to successfully synthesize TNT in a project examining the illicit transport of TNT dissolved in gasoline. Further, an art student was inspired to investigate the chemistry and synthesis of paint pigments, which in turn led to an entire series of artistic works.

One factor that has aided in the stimulation of new student-generated research projects is the end-of-semester seminar that has been institutionalized at SFCC for some time. Initially, this conference was established as part of the curricular changes in the biology and chemistry courses for science majors, in which students were required to present their group and/or individual research projects. After the first two years of curricular change, the conference was incorporated into the science courses for non-majors as well. Subsequently, as the embedded course research projects began to inspire additional, extracurricular research projects, the one-day conference for course projects ultimately expanded to three days to accommodate all the presentations from biology and chemistry majors, non-majors, and these students' independent research projects. This end-of-semester research conference grew beyond any expectation as faculty, staff, and students campus-wide began to attend the conference at some point over the three-day period. Essentially, the integration of research into the undergraduate science curriculum at SFCC shifted a science program that had only rarely had a student interested in pursuing research to a program with an average of 36 group research projects conducted as part of coursework per semester (with working groups of from two to four students), plus from four to 10 group and individual research projects each year conducted outside of coursework.

Surprisingly, an additional impact from the undergraduate research program at SFCC was made clear as students began to request research opportunities from faculty members in other disciplines. Not only were there requests in other sciences, but also in history, psychology, and sociology. At the last end-of-semester conference, invitations to present their research were extended to students in all disciplines at SFCC. Although no one from outside the science disciplines accepted this invitation, time will tell if the conference expands into all disciplines.

The institutional attitude toward undergraduate research has changed considerably. Even though SFCC faculty have such high teaching loads that they are afforded little opportunity to pursue additional scholarship, a sense of true "teaching scholarship" began to develop as the integration of undergraduate research into the curricula became the common practice in the sciences. Most notably, scholarly collaborations began to evolve. Not only were student/student and student/faculty collaborations becoming more common, but more faculty/faculty collaborations also developed. Although collaboration among science faculty members was the foundation of the initial changes, the small number of faculty and the increased demand for research opportunities necessitated deeper collaboration efforts in order to manage the research projects students wished to pursue.

Moreover, the small number of science faculty also meant a smaller pool of expertise to draw upon, which increased the need to rely on each other to find sufficient expertise to cooperatively supervise the undergraduate research projects across disciplines. Once these collaborations were recognized across the campus, other cross disciplinary faculty/faculty collaborations began to develop. For example, three faculty members—one each from biology, sociology, and psychology—worked together to develop and offer a research-based course on human sexuality. Another collaboration between biology and history faculty members led to significant improvements in teaching the historical context of conservation efforts in a wildlife conservation course. And another collaboration developed between chemistry and English composition faculty to offer a pair of courses in chemistry and compositional writing. Students in a chemistry course for non-majors use their experiences in the course as the basis for much of the writing they are assigned in their composition course.

Second-year biology student, Daniel Meenen (left) and second year pre-pharmacy student Emily Klein (right) set up their E. coli colonies to replicate the Hershey-Chase experiments that demonstrated DNA as the molecule of inheritance.

Even with all of the outcomes discussed here, the most important result is the impact that the incorporation of undergraduate research into the curriculum and the offering of extracurricular research opportunities have had on students. A noticeable increase in student confidence became apparent through an increase in students' ownership of their own education; they became more self-motivated, independent thinkers taking responsibility for their own learning. Increased student confidence resulted in increased course retention; many science courses at the beginning of this process had retention rates of less than 60 percent but at the end of this process, their overall retention rate was more than 90 percent. Students demonstrated, and continue to demonstrate, a greater desire to pursue careers in or related to research. When considering the impact on students and the institution at large, we were left with one question: Why didn't we do this before?

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LaRoy S.E. Brandt

Truman State University, lbrandt@truman.edu

LaRoy Brandt received a PhD in entomology from the University of Kansas, his MS in biology from the University of Central Missouri, and his BS in biology from Missouri State University. Brandt conducted numerous undergraduate projects, and studied the ecology of prairie mole crickets for his MS thesis and the behavioral ecology of the lesser waxmoth for his PhD dissertation. He taught various biology courses for State Fair Community College from fall 2002 through spring 2010. During his time at SFCC, he served for five years as department chair and managed to obtain external funding to develop a biotechnology program. For the past four years, Brandt has taught summer courses in tropical ecology, entomology, and field photography at the LaSuerte Biological Field Station in Costa Rica. Currently, Brandt is an assistant professor of biology at Truman State University in Kirksville, MO.

Jack Lee Hayes has a master's of science in analytical organic chemistry from Indiana University Bloomington, a masters of art of teaching adult and distance education from The University of Phoenix. Jack has served in the US Navy as an engineering laboratory technician (submarine qualified). Additionally, he was a project manager for Chem. Nuclear Inc., conducting waste disposal and site remediation. He conducted undergraduate research in environmental chemistry focused on surface water nutrients, and conducted graduate research in analytical electrochemistry for catalyzed reduction of chlorofluorocarbons. Hayes has served for eight years at various community colleges, teaching basic skills courses in addition to non-major, allied health, elementary organic, and introduction to biochemistry courses. For the past six years, Hayes has served as the lead chemistry instructor at State Fair Community College in Sedalia, MO where he teaches introductory chemistry, general chemistry, and organic chemistry courses.