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Summer 2017 | Volume 37, Number 4

UNDERGRADUATE RESEARCH AND HIGHER EDUCATION OF THE FUTURE

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COUNCIL ON UNDERGRADUATE RESEARCH

Summer 2017 Volume 37, Number 4

Publisher
CUR National Office
Council on Undergraduate Research
734 15th Street NW, Suite 850
Washington, DC 20005-1013
Phone: 202-783-4810
Fax: 202-783-4811
www.cur.org

Design
Design and Prepress Production
SliceWorks
Gaithersburg, MD
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Production and Mailing
The Sheridan Press
Hanover, PA
www.sheridan.com

The *Council on Undergraduate Research Quarterly* is published in the Fall, Winter, Spring, and Summer by the Council on Undergraduate Research.

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About the cover: Interns from the NASA Community College Aerospace Scholars program gather at Johnson Space Center in Houston; NSF S-STEM scholar Diego Fernandez (Suffolk County Community College) is third from right, upper row. Photo courtesy of NASA.

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CUR Focus

Candice J. Foley and Nina Leonhardt, *Suffolk County Community College*

Partnerships and Collaborations Impacting Student Research Programs at Community Colleges

Abstract

The authors discuss efforts at New York's Suffolk County Community College to engage minority and nontraditional students in STEM research and presentation opportunities. Using mixed methods and quantitative descriptive analysis, their research examines the impact of extended research experiences on the students' academic and career paths. The 182 students in the NSF S-STEM cohorts from 2007 to 2016 had dramatically higher retention and graduation rates as well as GPAs when compared to their STEM peers not enrolled in the NSF S-STEM program. Findings indicate that community college student researchers perform better academically than their peers who chose a more traditional path and that success in STEM encourages increased college persistence.

Keywords: *community colleges, minority student retention, partnerships, STEM, undergraduate research*

Community colleges are an undervalued resource with the potential to help many students move through STEM degree programs and enter STEM careers. More than half of all undergraduates begin higher education at a community college. However, more than two-thirds of community college students who declare a STEM major do not complete that degree, according to a 2014 report by the National Center for Education Statistics (NCES 2013) and the 2016 fact sheet of the American Association of Community Colleges (AACC).

Those all-important first two years of STEM education for many students takes place at the often-overlooked community-college level. According to the AACC, community-college students composed 49 percent of all undergraduates, and 43 percent of first-year students in 2016, including those who went on to pursue STEM careers. According to the National Science Foundation's Science and Engineering Indicators 2016, almost 20 percent of U.S. residents who were awarded science and engineering doctoral degrees, and 46 percent who graduated with bachelor's and master's degrees in science and engineering in recent years, earned credits at a community or two-year college. In 2013, 86,000 of more than 1 million associate's degrees (8.6 percent) were in science and engineering fields.

The National Survey of Student Engagement indicates that active and collaborative learning are critical indicators of student engagement and therefore student success (NSSE 2016). Undergraduate research opportunities, which are active and collaborative experiences, attract and retain community college students in the STEM fields that are crucial to the country's economic success and global competitiveness. These high-impact best practices are cited as especially important for traditionally underrepresented populations.

However, there are challenges posed by limited on-site research facilities and large faculty teaching loads. Partnerships and collaborations with research-based institutions can mitigate these challenges. By leveraging professional networks of involved community partners, faculty members, and administrators, initial outreach to research sites can yield student opportunities (Amey, Eddy, and Ozaki 2007).

At Long Island's Suffolk County Community College (SCCC), these challenges have been met through valuable networks with regional colleges and universities, as well as with nearby Brookhaven National Laboratory (BNL) and the national laboratory system. To a large extent, these networks of partners and collaborators have grown from individual collaborations.

SCCC has secured 15 years of consecutive funding through NSF's S-STEM program to financially and academically support STEM students. Awarded in October 2016, the latest grant Support for Undergraduates at Community College Engaged in STEM Studies (SUCCESS) will reduce barriers affecting achievement gaps and increase the number and scope of STEM research opportunities by providing additional scaffolding to strengthen educational outcomes for SCCC's STEM scholars.

Theoretical Underpinnings

The SUCCESS program is based on the importance of partnerships and collaborations, which provide extended venues for early research and build a sense of a large STEM community. Diversity of thought and expanse of resources are cited as the rationale for partnerships and collaboration, particularly at the community college. Collaborative relationships in support of research provide the best possible learning experiences for future STEM professionals and help develop workplace/lab skills. Collaborations bring together people with different ideas and approaches, which leads to innovation (Pinelli and Hall 2012; Amey et al. 2007). These relationships must be beneficial to all stakeholders for the partnership to be sustained. For example, Research Experiences for

Undergraduates (REU) sites can benefit from a cost-sharing arrangement that may be accomplished through grant funds. It is essential that the community college program organizers nurture the collaborations with off-site research programs by attending symposia that usually conclude such experiences. In this manner, support of early research at the community college can solidify the partnerships.

The literature addresses the value-added of early research to foster increased scientific literacy, intellectual curiosity, and improved employment prospects. These factors further contribute to a growth in technical skills and critical thinking skills (Malcolm and Feder 2016; Hensel and Cjeda 2014; Pinelli and Hall 2012). The importance of student research opportunities has been broadly recognized nationwide, as Oregon State University has highlighted through its podcast series *Research in Action*.

Partnerships and Collaborations

Suffolk County Community College's STEM ecosystem (see Figure 1) is a continually developing and symbiotic network that benefits all parties (Rundell-Singer 2015). Originally collaborations between individuals who had worked together, this ecosystem is now composed of formal arrangements, complemented by the longstanding informal personal collaborations that are based on trust.

The formative collaborations were based on information sharing—data, activities, and plans. These trust-building actions led to meeting the needs of the collaborators and the beginnings of formal memoranda of agreement. Research sites required students to fulfill their missions and grant-funded objectives while Suffolk students desired options for research in authentic settings. Today, partners routinely confer about academics, student transfer options, conference support, and proposal generation. Capacity has been expanded at the community college for both students and faculty (Hirst et al. 2014); research institutions have a pipeline of researchers to contribute to innovations.

Program Description

The SUCCESS program resulted from a collaborative network and is constantly informed by interactions with network partners (see Figure 1). It is designed to increase the number of low-income, academically talented STEM students who graduate, transfer to a four-year program or directly enter the STEM workforce. The program develops, scales, and enhances student support, curricular activities, and early research opportunities via internal and external partnerships and collaborations. Students majoring in a STEM discipline with a GPA of at least 2.8 and with financial need as determined by SCCC's Office of Financial Aid are invited to apply to the NSF S-STEM program. Once admitted, students can access community- and network-building events, a scaffolded mentoring system, advisers and professional tutors, and early research opportunities considered as best practices for engaging community college students and contributing to their academic growth (see Table 1). The scholarship support, authentic research experiences, networking, and community-building activities—coupled with the network of partnerships and collaborations with STEM champions in local, regional and national arenas—indicate significant gains in STEM student performance, retention, completion, and transfer, which are critical to STEM persistence.

Internal partners and collaborators include SCCC's STEM departments and faculty; the American Chemical Society (ACS)

Figure 1. Suffolk County Community College's STEM Ecosystem

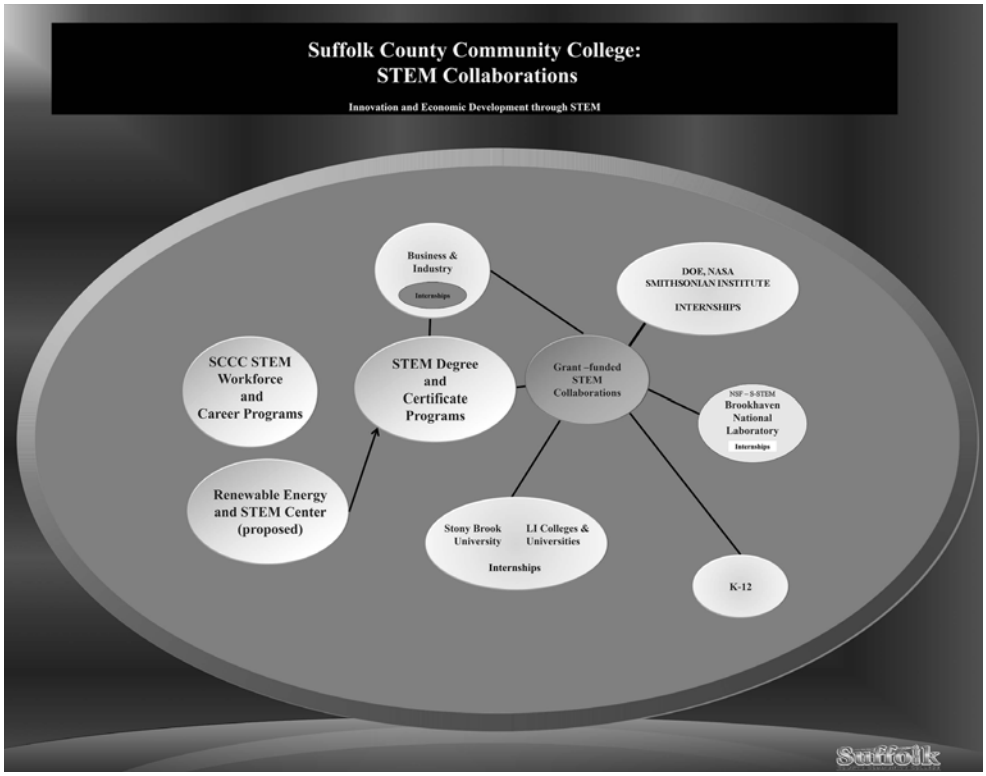

Table 1. Program Elements

Program Elements	Activities	Partnerships and Collaborations
Retention through community building among S-STEM scholars within the institution	• NSF S-STEM scholars meet formally approximately 15 times per year • Monthly meetings host invited speakers who are diverse in terms of ethnicity and gender (50 percent), and 80 percent of speakers are drawn from partners and collaborators	• STEM clubs and programs: ACS, Engineering/Technology, CSTEP, STEP • Monthly meeting held jointly with NYS CSTEP students • One-on-one networking provided by diverse role models and potential career and academic mentors lowers societal and aspirational barriers for STEM scholars to explore and apply talents and skills to new and unique arenas not previously considered
Tutors, study groups, and supplemental instruction programs through academic support service	• Individualized, discipline-specific, one-on-one tutoring sessions • NSF S-STEM projects office for informal STEM scholar community, study groups, and networking at nonresidential college: videoconferencing; 3D and poster printing • Annual field trip to Mohonk Preserve (NY) and Stony Brook University • Convergences with other grant-funded programs: IRACDA, LSAMP, ATE, SENCER, Helmsley, LICF • Introduction to Research Methods (IRM) course developed as academic complement to off-site research experiences of many students	• Peer-to-peer mentoring by NSF STEM scholars of local secondary school (STEP) students • Researchers at Mohonk Preserve provide access to daily database of oldest U.S. archived weather data • Peer-to-peer: Underrepresented Stony Brook students lead tour and provide guidance • IRACDA and LSAMP consortial partnerships provide mentoring and paid research internships • Cross-disciplinary SENCER and HCT projects involve faculty/students in civic engagement study "Water Quality on Long Island" • LICF provides intensive tutoring to lower barriers for transfer and persistence • IRACDA postdoctoral teaching fellows partner with multidisciplinary STEM faculty for IRM course development and implementation-subsequently offered to SBU and Nassau Community College partner students
Support and mentoring of students by faculty and other professionals	• Each NSF S-STEM scholar is paired with at least one discipline-specific faculty mentor.	• Faculty mentors provide academic and career guidance on a monthly basis. • Faculty mentor research scholars at federal lab via the FAST (Faculty and Student Teams) program • Peer-to-near-peer mentoring of research scholars by IRACDA postdoctoral teaching fellows from SBU and/or NSF S-STEM alumni peer-mentor scholars
Early research internship experiences	• 54.2 percent of STEM scholars engaged in early collegial and research opportunities at local colleges and universities and regional and national research centers (58/107 for 2011–2016) • Competitive selection of students to participate in paid summer research at national labs, NASA, and REUs (See Figure 2 for locations within the United States and abroad)	• BNL, SBU, and LI STEM Hub business and industry mentors provide access to research opportunities, internships, job shadowing experiences, and professional experiences • BNL annual "mini-semester," a one-week intensive immersion experience for undergraduates considering research • Offers to students by national labs/REUs to continue their research after conclusion of summer research internships • Employment at national labs • Scholarship offers for students to continue their education
Participation in regional professional, industrial, or scientific meetings and conferences	• Student researchers present posters/papers individually or with student/mentor/faculty collaborators from other institutions at local, regional, and national conferences and competitions such as Science and Energy Research Challenge (SERCh), National Conference on Undergraduate Research, Emerging Researchers National Conference, and NASA	• Student researcher presentations at academic partner symposia, including SBU, Farmingdale State College (SUNY), BNL, annual CSTEP statewide conference, and annual SUNY Undergraduate Research Conference • Student research presentations at the LI STEM Hub Annual conference

student chapter; the student Technology Club; the New York State Education Department's Collegiate Science & Technology Entry Program (CSTEP) and the Science & Technology Entry Program (STEP) for secondary students; the Science Education for New Civic Engagements and Responsibilities (SENCER) initiative, NSF Advanced Technological Education (ATE) projects; the National Institutes of Health (NIH) Institutional Research and Academic Career Development Award (IRACDA) projects; and the NSF Louis Stokes Alliance for Minority Participation (LSAMP) projects. In addition, two private foundation awards, the Helmsley Charitable Trust (HCT) and the Long Island Community Foundation (LICF), support the program.

External partners and collaborators include BNL, the State University of New York (SUNY) administration and its applied learning division, SUNY institutions throughout New York such as Stony Brook University (SBU), the Empire State STEM Learning Network, and the Long Island STEM Hub.

Existing STEM initiatives have been applied to programs so that additional and more varied benefits and services may be provided. Two previous and successful NSF S-STEM programs created SCCC's robust STEM learning community and provided financial support for high-achieving, underrepresented students. Both programs were highly effective in transitioning scholars to four-year institutions to continue their STEM education. Project survey data to date mirror those identified in the science education literature (Basu and Barton 2007; Bystydzienski and Bird 2006): students learn best in authentic settings, excel in communities with support, and show interest in emerging STEM fields and the environment.

A small grant from the LICF funded a pilot program (2012–2014), which implemented one-on-one course-specific tutoring and targeted support services above and beyond the scope of existing programs. This pilot program provided direct evidence of the benefits of scaling and sustaining these programmatic supports to both lower curricular barriers and strengthen the ability of academically talented, financially needy STEM scholars to achieve timely completion of their associate degrees. This form of targeted support is now funded through SUCCESS.

A crucial community element is the peer-to-peer mentoring initiative, which has been recognized by the previously mentioned studies as a means to lower the barriers of gender perceptions and increase success of STEM scholars. Near-peer mentoring is also provided by a collaborative NIH grant with SBU: the Institutional Research and Career Development Award (New York Consortium for the Advancement of Postdoctoral Scholars) involves postdoctoral fellows at SBU mentoring NSF S-STEM scholars engaged in summer research, thereby expanding the students' STEM community.

Finally, since community college students embarking on authentic, self-directed research for the first time may not be familiar with a literature review, the identification of research questions, statistical methods, and the presentation of results, SCCC implemented an online Introduction to Research Methods course. This three-credit course prepares students to begin research as active participants; SUCCESS is structured to pay the tuition cost. After completing the course, students are prepared to analyze their results and present findings at conferences, and are encouraged to publish in SCCC's online student journal. The online modality permits SUCCESS students to take this course prior to their research experience or as a complement to the actual research activity; they also have the option to take it on campus or at any of the partner sites.

Authentic Research Internships, Presentation Prospects, and Publication Opportunities

The authentic active-learning methodology and paid research internship experiences at more than half of the nation's federal laboratories and SBU's REUs are the pedagogic centerpieces of STEM programs at SCCC, which have positively affected student engagement and performance. The program focuses on strategies to empower scholars to develop professionally as they continue their academic journey.

At SCCC, research experiences are a premier goal for all STEM students. The benefits are made clear through the insights shared by the invited speakers. Students are made aware of such opportunities throughout the program and receive encouragement from project leaders, mentors, and STEM department faculty to apply. Project leaders indicate which programs are best suited to each student, based upon their academic credentials. For example, a first step is often the BNL mini-semester or a university REU, as national laboratories require at least one full year of math and science courses.

Next, NSF S-STEM program students are encouraged to apply for opportunities at NASA and government laboratories such as BNL, Lawrence Berkeley National Laboratory in California, Oak Ridge National Laboratory in Tennessee, Pacific Northwest National Laboratory Washington, Idaho National Laboratory in Idaho, and Los Alamos National Laboratory in New Mexico. After the first such experience, they are often invited by laboratory researchers to return the following summer. To date, 82 of the 182 NSF S-STEM scholars who enrolled in the program from 2007 through 2016 have been active researchers, and 44 percent have participated in paid research internships. Table 2 lists representative titles of student research projects and host institutions. Figure 2 represents the broad array of geographic student research.

Table 2. Selected Student Research Projects

Research Poster/ Presentation Title	Internship	Laboratory location	Presentation venue(s)
"Generation of TALEs to Block REST RE-1 Site Interactions"	SUNY Chancellor's Biomedical Education Pipeline Research	Stony Brook University	Stony Brook University Symposium 19th Annual Pine Barrens Research Forum at Brookhaven National Laboratory
"Troubleshooting, Project Management, and Asset Tracking of HVAC Systems"	DOE Community College Internship	Brookhaven National Laboratory	Brookhaven National Laboratory Symposium 19th Annual Pine Barrens Research Forum at Brookhaven National Laboratory
"Effect of Histone Deacetylase Inhibition on Radiosensitivity of Primary Human Fibroblasts Following Charged Particle Irradiation"	DOE Community College Internship	Brookhaven National Laboratory	Brookhaven National Laboratory Symposium National Conference on Undergraduate Research, Spokane, WA First annual SUNY Science Undergraduate Research Conference: SUNY Brockport 19th Annual Pine Barrens Research Forum at Brookhaven National Laboratory
"The Effect of Toca 1 on Cluster Induced Endocytosis Internalization and Colocalization in Raft Mediated Endocytosis"	DOE Community College Internship	Brookhaven National Laboratory	Brookhaven National Laboratory Symposium National Conference on Undergraduate Research, Lexington, KY NSF student panelist for S-STEM projects meeting, Arlington, VA
"Development of New Diagnostic Tools for Battery Materials"	DOE Science Undergraduate Laboratory Internship	Lawrence Berkeley National Laboratory, Berkeley, CA	SULI Research Symposium at Lawrence Berkeley National Laboratory
"Developing a Technique for Chromium Speciation Analysis Using Inductively Coupled Plasma Optical Emission Spectrometer"	DOE Community College Internship	Pacific Northwest Laboratory, WA	Second Annual SUNY Science Undergraduate Research Conference, SUNY Cobleskill "Exploration and Observation: Undergraduate Student Research and Creative Activities Forum," Albany, NY
"NASA: Utilizing 'iDepths' to Probe Mars"	National Aeronautics and Space Administration (NASA)	Johnson Space Center, Houston, TX	Second Annual SUNY Science Undergraduate Research Conference, SUNY Cobleskill "Exploration and Observation: Undergraduate Student Research and Creative Activities Forum," Albany, NY
"Quantifying Isobutane Leakage Rates from Binary Geothermal Poster Plants"	DOE Community College Internship	Idaho National Laboratory, Arco Desert, ID	"Exploration and Observation: Undergraduate Student Research and Creative Activities Forum," Albany, NY Second Annual SURC: SUNY Undergraduate Research Conference, SUNY Cobleskill "Advanced Energy Conference," Jacob Javits Convention Center, New York, NY
"Analysis of Various Schemes for the Estimation of Atmospheric Stability Classification"	DOE Community College Internship DOE Science Undergraduate Laboratory Internship	Brookhaven National Laboratory	Brookhaven National Laboratory Symposium 2012 Emerging Researcher National Conference in STEM, Atlanta, GA "Exploration and Observation: Undergraduate Student Research and Creative Activities Forum," Albany, NY
"Sustainment of Meteorological Sensors on the Long Island Solar Farm"	(2) DOE Community College Internship (1) Research Experiences for Undergraduates	Brookhaven National Laboratory 2011 REU Stony Brook University 2010	Brookhaven National Laboratory Symposium 2013 Emerging Researcher National Conference in STEM, Washington, DC

Figure 2. Geographic Impact

Students also learn important communication and self-management skills that contribute to their future career success. Faculty mentors and counselors assist students in synthesizing acquired practical skills. Student researchers are encouraged to present their findings locally, regionally, and nationally. Annual venues include the Long Island STEM Diversity Summit, the Long Island STEM Hub Annual Celebration, the Long Island Pine Barrens Research Forum, BNL, the SUNY STEM Diversity Summit, SUNY Undergraduate Research Conference, the National Conference on Undergraduate Research, the Emerging Researchers National Conference, and the Columbia University Research Symposium.

Findings

Data from SCCC's Office of Planning and Institutional Effectiveness (2016) indicate that the program is making a difference in STEM student success relative to persistence, graduation, and transfer in STEM. The NSF S-STEM cohorts (N=182) of 2007–2008 to 2015–2016 had significantly higher GPAs, on average, than their STEM peers (N=8531) who were not in the NSF S-STEM program (3.32 vs. 2.67). Also, the semester-to-semester retention rate for the NSF S-STEM cohorts was significantly higher (86.5 percent vs. 68.5 percent), and they graduated at more than twice the rate of their STEM peers who were not in the NSF S-STEM program (58.2 percent vs. 28 percent).

Additional critical comparative data (Office of Planning and Institutional Effectiveness 2016) indicate that research internships also have a positive effect on persistence and success. NSF S-STEM students transferred after graduating at a significantly higher rate than their STEM peers who were not in the NSF S-STEM program (54.7 percent vs. 36.9 percent), and the NSF S-STEM Research Scholars had a higher GPA, on average, than their NSF S-STEM peers (3.47 vs. 3.31). Finally, NSF S-STEM Research Scholars transferred after graduating at a significantly higher rate than their NSF S-STEM peers (71 percent vs. 48 percent).

Conclusion

Suffolk County Community College has successfully leveraged local, state, NSF, and business and industry partnerships/collaborations over the last 10 years to serve a region with high-technology research and industry requirements and some of New York's largest communities of individuals underrepresented in STEM. Partnerships and collaborations have sought to provide authentic student research and presentation opportunities with student-identified civic engagement themes so that minority and nontraditional student involvement in STEM is increased. Such initiatives strengthen the workforce pipeline by bolstering student recruitment, retention, graduation, and transfer, thus working to fulfill local and national workforce needs in STEM.

This focus aligns with SUNY's effort to require applied learning for all of its graduates. The future of higher education is tied to its relevance to authentic skills, and early student research opportunities—with their strong network of partnerships and collaborations—are among the best vehicles to provide such experiences.

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Nina Leonhardt is associate dean at Suffolk County Community College (SCCC) and spearheaded SCCC's NSF-funded SENCER project, leading faculty in the development of student-centered active learning in climate change and sustainability. She served as an implementation strategist and community college research associate to Battelle's STEMx network, a charter member of the Empire State STEM Learning Network, and a member and leader of

the Long Island STEM Hub. She previously served as educational programs manager at Brookhaven National Laboratory, adjunct instructor in the Department of Technology & Society at Stony Brook University, and special projects consultant for the Science Education Program at New York University. Leonhardt holds an MS in electrical sciences and a BA in education from Stony Brook University and an MBA from Dowling College.

doi: 10.18833/curq/37/4/16

Coming Up in SPUR

Winter 2017:
"Innovative Learning Spaces That Promote Undergraduate Research"

CURQ Vignettes

Interdisciplinary Design Teams for Biomedical Engineering Design

Conrad Zapanta, Wayne Chung, and Joanna Dickert
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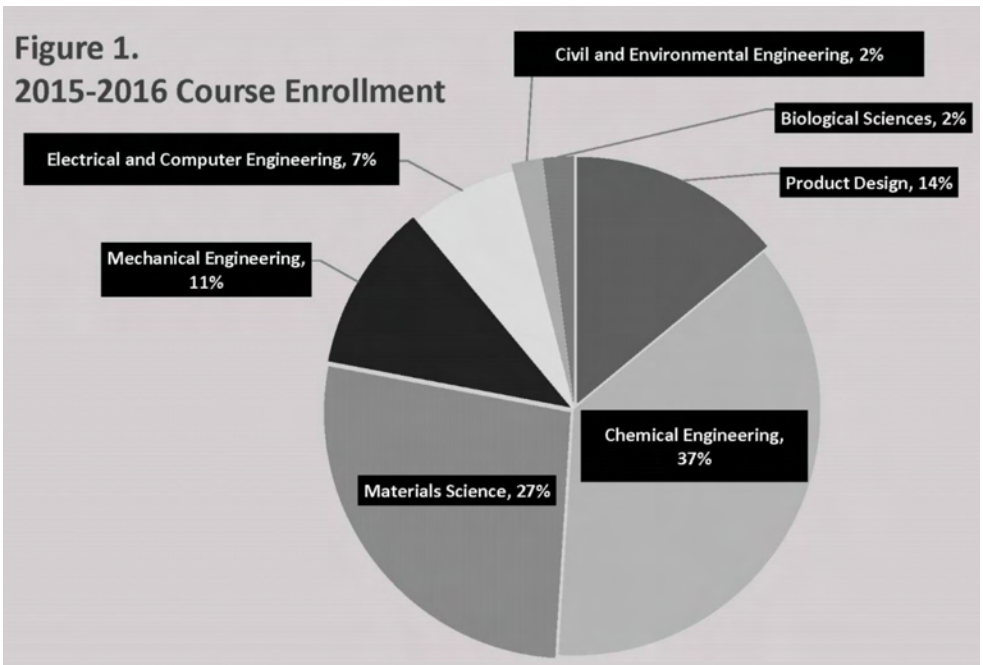
In the medical device industry, diverse project teams historically create innovative solutions. From corporate medical organizations to engineering and design consulting firms such as GE Healthcare and IDEO, evidence suggests that interdisciplinary teams that work together throughout the entire design process create successful products. However, there are few opportunities for this type of educational experience available to undergraduate students. The Biomedical Engineering (BME) Design course sequence at Carnegie Mellon University introduces BME students from the College of Engineering and product design students from the College of Fine Arts to the development of useful biomedical products in a one-year, research-based experience.

At Carnegie Mellon, BME undergraduates must declare a primary major in one of the other departments in the College of Engineering. Options include chemical engineering, civil and environmental engineering, electrical and computer engineering, materials science and engineering, and mechanical engineering. Grounded in the belief that a biomedical engineer must be deeply trained in both traditional engineering practice and biomedical sciences, this requirement benefits from extensive collaborations with sister departments and major medical institutions in Pittsburgh. This collaborative approach, combined with a rigorous engineering education, confers unique depth and breadth to the BME curriculum.

The BME Design course is a graduation requirement for all BME majors at Carnegie Mellon. Although it is not a requirement for product design majors, enrollment reflects significant intellectual diversity as shown in Figure 1. The dynamic composition that shifts each year presents both opportunity and challenge, as course instructors create diverse yet balanced teams with relevant prior experience and skill sets.

In teams ranging in size from four to six, juniors and seniors collaborate to develop a product or device that meets a specific medical need. Teams are selected based on student input, project interest, and the Comprehensive Assessment for Team Member Effectiveness (CATME) system. CATME is a set of tools designed to optimize student experiences in team-based projects. BME Design course instructors use the CATME Team Maker and the CATME Peer Evaluation modules. The CATME Team Maker system ensures team diversity, incorporating considerations such as project preference, class schedule, student primary major, software skills, leadership styles, and big-picture/detail orientation preferences.



In addition to creating a classroom environment in which students collaborate across disciplinary boundaries, the course experience is supported by robust internal and external partnerships. For some project teams, industry partners function as clients, presenting needs to be addressed. Other teams develop their own project ideas. Funding for these projects is provided by the corporate client or by Carnegie Mellon's Undergraduate Research Office (URO). In the fall 2015 semester, URO staff members also began to participate in designated course meetings, providing course-specific guidance relative to proposal writing and project presentations.

During the fall semester of the course, students learn to identify product needs and specify problem definitions. This product ideation is

followed by completion of an initial prototype and authorship of a written design brief. Opportunities for peer review of this document during class meetings throughout the fall semester prioritize interdisciplinary engagement and build professional communication skills. During the spring semester, the focus shifts to product development, as the teams collaborate to develop a form model and iterative functional prototypes as well as marketing and manufacturing plans for their products. The course experience culminates in team presentations during the university-wide undergraduate research symposium.

CATME peer-evaluation survey results indicate that interdisciplinary teams generally have higher satisfaction than teams composed solely of engineers. The CATME peer-evaluation survey was administered three times over the course of the academic year. In each iteration, students provide self-evaluation scores as well as a score for each of their teammates on the following characteristics:

- Having relevant knowledge and skills (H)
- Interacting with teammates (I)
- Contributing to the team's work (C)
- Keeping the team on track (K)
- Expecting quality (E)

Teams with students from four or five different majors demonstrated higher average scores across each of these categories than teams with representatives from one or two majors.

Direct and indirect assessment measures offer evidence of student learning gains related to written and oral communication competencies with evidence of greater gains since the inception of the formal partnership with the URO. An independent panel of university faculty and staff reviews and scores project funding requests submitted to the URO. All of the proposals were funded for the 2015–2016 course sequence, with five funded in full, in contrast to 33.3 percent that were funded in the previous year. On a scale of 1–5 with 5 as the highest possible score, the average rating for proposals from students in the BME Design course sequence increased from 3.22 for the spring 2015 funding cycle to 3.50 for the spring 2016 funding cycle. Results from the post course iteration of the Classroom Undergraduate Research Experience (CURE) Survey provide student self-assessments of learning in this domain. Respondents (n=17) reported above average gains in their abilities to write a research proposal, present results orally, present results in written papers or reports, present posters, and critique the work of other students. Administered by David Lopatto, professor of psychology at Grinnell College, the CURE survey report includes course-specific results as well as nationally normed data drawn from all participating courses.

In addition, several interdisciplinary teams have won design awards in external competitions such as the BME Start competition sponsored by VentureWell, the MIT Enterprise Forum, and the Social Finance Global Innovation competition sponsored by BNY Mellon. Many teams have also continued commercial development of their design projects after the completion of the course. One such example is the Calibrace+, a flexible brace that alleviates posture issues in patients with Parkinson's disease. Initially developed as the People Prop by a BME design team, it is being marketed commercially by Abilife.

doi: 10.18833/curq/37/4/17

Research-Intensive Course Designation

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Integrating undergraduate research into the curriculum is growing in popularity within academic institutions. This practice provides an opportunity for faculty to expose and engage more students to authentic research practices within their courses and scaffold the development of research skills toward a capstone research experience. The process of recognizing research-intensive activities on student transcripts remains limited at many institutions to honors students and through formal theses. A need exists to provide evidence of additional curricular research-intensive activities that do not appear on student transcripts. Such activities could include individual or group classroom projects whereby students are actively engaged in the research process. For students, transcript designation is an opportunity to showcase their research accomplishments. For faculty, this practice can provide credit for intensive undergraduate research mentorship and be applied to annual reports and other promotion portfolios. A few institutions nationwide have begun the process of establishing institutional mechanisms for certifying and designating research-intensive courses. As part of institutional reaccreditation through the Commission on Colleges of the Southern Association of Colleges and Schools (SACSCOC), Florida Atlantic University (FAU) and George Mason University (Mason) implemented quality enhancement plans (QEPs), which included developing university-wide mecha-

nisms for certifying research-intensive courses. These models follow below.

Florida Atlantic University Research-Intensive (RI) Course Designation. Florida Atlantic University is a public university with high research activity, enrolling approximately 30,000 students (including 25,471 undergraduates) and ranking as the most diverse in Florida's 12-institution state university system. FAU encompasses six campuses across a six-county service region in South Florida, with more than 180 degree programs. FAU implemented a QEP, *Distinction through Discovery* (2013), to expand a culture of undergraduate research and inquiry across all campuses and programs.

Within this plan, FAU established a mechanism to recognize research-intensive, curricular activities through the research-intensive (RI) course designation. RI courses actively engage students in the process of original and/or applied research. Students address a research question and generate tangible research outcomes such as communicating results. Courses are taken for a letter grade of which a significant portion must be tied to the RI assignment. RI projects may be individual or group projects; however, each student receives an individual assessment. FAU has a separate course designation, directed independent research (DIR), for individualized, independent research activities.

FAU established a committee of faculty from all colleges, the Undergraduate Research Curriculum Committee (URCC), to launch the RI designation. The URCC serves as a subcommittee of the University's Undergraduate Programs Committee. The URCC crafted an RI Designation Manual that includes RI definitions, application guidelines, and course submission procedures. Faculty submit a course syllabus and cover letter that demonstrate how the course meets the student learning outcome and RI requirements. After department and college approvals, the URCC reviews portfolios and provides recommendations or revisions. Final approval occurs through the faculty senate. The RI designation may be applied to individual sections of courses and/or the entire course. RI courses include the prefix "RI" in the course title; the designation appears on student transcripts. Course approvals began in spring 2016. To date, 27 RI courses and 76 DIR courses from four colleges have been approved. A three-year syllabi review process for certified courses ensures sustainability of RI activities in the curriculum.

George Mason University Research and Scholarship (RS)-Intensive Course Designation. George Mason University is a public university with high research activity located near Washington, DC, in Fairfax, Virginia. More than 198 degree programs serve a diverse population of almost 34,000 students (including 21,990 undergraduates). Mason adopted the *Students as Scholars* QEP (2011), a university-wide initiative to improve student success through increased participation in, and celebration of, undergraduate research and creative activities.

A central element of this QEP was establishing scaffolded learning experiences, culminating with research and scholarship (RS)-intensive courses. In RS courses, students conduct authentic scholarly work that composes a significant portion of the class, and students have the opportunity to disseminate their results beyond the classroom. RS courses are generally upper division, and departments are encouraged to designate both "classroom"-type and individualized scholarly activity ("independent research") courses. The registrar identifies RS courses with an RS attribute that appears on student transcripts. This designation is applied to entire courses, not just individual sections.

A faculty planning committee first proposed the RS designation and worked with the provost and registrar to approve and implement the designation. The plan was presented to the faculty senate and the Board of Visitors. Because the RS designation is not required for graduation, neither group needed to approve it.

Mason established a Faculty and Curricular Activities Committee (FCA) to review and approve courses. Faculty submit a portfolio that includes the syllabus, a narrative statement describing the course and a plan for sustainability, a curriculum map demonstrating course activities that meet student learning outcomes, and a statement of support from the chair. The FCA reviews the proposed courses. Outcomes can include approval as submitted, approval with minor revisions, return for revision, and denial. Since 2012, 80 RS courses have been approved in all undergraduate schools and colleges. The assessment and FCA committees review course portfolios (including revised syllabi, a faculty reflective statement, and student work samples) after the first incarnation of the course and after any significant changes to the course.

Conclusion. The experience with research-intensive courses shows that several elements of the process are vital to institutional success:

- *Broad faculty participation* to define the course criteria (percentage of the course grade associated with the research requirement, student learning outcomes, instructor requirements, and research outcomes)
- *Establishment of a review mechanism* within the institution

- *Interaction with the registrar's office* to ensure feasible processes for transcript designation
- *Assessment* of the courses to ensure sustainability
- *Support of faculty* as they develop, submit, and teach the courses
- *Direct communication with students* to let them know the benefits of the courses and encourage registration

Other higher education institutions should consider designating research-intensive courses in student transcripts, as such a practice helps to develop a shared understanding of student research across disciplines as well as demonstrate student involvement in the diverse conduct of research across institutions.

References

Florida Atlantic University. 2013. *Distinction through Discovery: Expanding the Culture of Undergraduate Research and Inquiry* [Quality Enhancement Plan]. http://www.fau.edu/ouri/Quality_%20Enhancement_Plan_1_11_13.pdf

George Mason University. 2011. *Fostering a Culture of Student Scholarship: Students as Scholars* [Quality Enhancement Plan]. http://oscar.gmu.edu/upload/Students-as-Scholars-QEP.pdf

doi: 10.18833/curq/37/4/18

UNDERGRADUATE RESEARCH Highlights

Freeburg SH, Engelbrecht E, Powell WH. Subfunctionalization of Paralogous Aryl Hydrocarbon Receptors from the Frog *Xenopus laevis*: Distinct Target Genes and Differential Responses to Specific Agonists in a Single Cell Type. *Toxicological Sciences*. 2017; 155:5: 337–347. doi:10.1093/toxsci/kfw212. (Kenyon College)

We used TALENs to knock out individual paralogous Aryl Hydrocarbon Receptor (AHR) genes in a cell line from the frog *Xenopus laevis*. Characterization of the mutant cell lines exposed to two different agonists revealed that each receptor exhibits different transcriptional regulatory functions. Wade Powell is a professor of biology. Scott Freeburg is a PhD student at Harvard University. Eric Engelbrecht, a lab technician at Boston Children's Hospital, worked on this research as an undergraduate. This research was supported by NIH AREA Grant 2 R15 ES011130-05 (to WHP) and the Kenyon College Summer Science Scholars Program.

Deaton CD, Hein CJ, Kirwan, ML. Barrier Island Migration Dominates Ecogeomorphic Feedbacks and Drives Salt Marsh Loss along the Virginia Atlantic Coast, USA. *Geology.* 2016; 45:123–126. doi:10.1130/G38459.1. (Virginia Institute of Marine Science, College of William and Mary)

Coupling between barrier islands and their associated salt marsh and tidal flats leads to complex feedbacks that are proposed to control the response of barrier-island systems to sea-level rise. This study tested the applicability of these concepts through investigation of the Virginia barrier islands. Using historical maps and photographs from 1851 to 2010, we determine that rapid landward island migration is leading to backbarrier area reduction and large-scale salt marsh loss (19 percent). Landward barrier-island migration was responsible for 51 percent of marsh loss, with the remainder due to backbarrier processes (e.g., edge erosion). These results indicate that, for barrier island systems already undergoing migration, the primary barrier-backbarrier coupling is the loss of marsh and tidal-flat area because of barrier-island migration itself. Charles (Charlie) Deaton completed this work as part of his senior thesis at the College of William and Mary, from which he graduated in 2015. Deaton is now completing his master's degree at the University of North Carolina at Chapel Hill. Christopher Hein and Matthew Kirwan are assistant professors at the Virginia Institute of Marine Science. This work was supported by NSF LTER (1237733) and Coastal SEES (1426981 and 1325430) programs.

Smolyaninova VN, Jensen C, Zimmerman W, Prestigiacomo JC, Osofsky MS, Kim H, Bassim N, Xing Z, Qazilbash MM, Smolyaninov II. Enhanced Superconductivity in Aluminum-based Hyperbolic Metamaterials. *Scientific Reports*. 2016; 6: 34140. doi:10.1038/srep34140. (Towson University, Naval Research Laboratory, College of William and Mary, University of Maryland–College Park)

One of the most important goals of condensed matter physics is materials by design, i.e. the ability to reliably predict and design materials with a set of desired properties. A striking example is the deterministic enhancement of the superconducting properties of materials. We have engineered an aluminum/aluminum oxide hyperbolic metamaterial capable of a significant enhancement of superconducting critical temperature, while having superior transport and magnetic properties compared to the core-shell metamaterial superconductors. Vera Smolyaninova is a professor of physics and Christopher Jensen is a graduate student at Towson University. William Zimmerman, physics major at Towson, participated in the research for independent study credit. Zimmerman graduated from Towson University in May 2016 and is enrolled in the professional master's program in applied physics at Towson. Joseph C. Prestigiacomo and Michael S. Osofsky are research physicists and Heungsoo Kim and Nabil Bassim are materials engineers at the Naval Research Laboratory in Washington, DC. Zhen Xing is a graduate student and Mumtaz Qazilbash is an associate professor in the Department of Physics at the College of William and Mary. Igor Smolyaninov is a research scientist in the Department of Electrical and Computer Engineering at the University of Maryland–College Park. This research was supported in part by Fisher College of Science and Mathematics Undergraduate Research and Towson Undergraduate Research Grants, which were awarded to Zimmerman, and by NSF grant DMR-1104676 at Towson.

Hoang NH, Kane ME, Radcliffe EN, Zettler LW, Richardson LW. Comparative Seedling Germination and Development of the Ghost Orchid, *Dendrophylax lindenii* (Orchidaceae), and Molecular Identification of Its Mycorrhizal Fungus from South Florida. *Annals of Botany.* 2017; 119: 3: 379–393. doi: 10.1093/aob/mcw220. (Illinois College; University of Florida)

The endangered, world renowned, leafless ghost orchid *Dendrophylax lindenii* is difficult to grow under artificial conditions. Critical information regarding asymbiotic and symbiotic (co-culture with a mycobiont) seed germination of this orchid is completely lacking in published sources and is nec-

essary for the development of efficient procedures for ghost orchid production for successful reintroduction. Mycorrhizal strain Dlin-394, isolated from ghost orchid roots in situ, was confirmed as a mycorrhizal associate, which significantly promoted seed germination and seedling development. Molecular ITS sequencing data identified the fungus as a previously unreported strain of Ceratobasidium. These results offer the opportunity to examine the benefits of using a fungus to enhance in vitro germination and possibly ex vitro acclimatization and sustainability following outplanting. Nguyen H. Hoang is a doctoral student at University of Florida and a research fellow in the Department of Plant Biotechnology at the University of Sciences in Vietnam. Michael Kane is a professor of environmental horticulture at the University of Florida. Lawrence Zettler is Hitchcock Professor of Biology at Illinois College. Ellen Radcliffe undertook this research project as part of a summer internship experience following her junior year at Illinois College in summer 2014. Larry W. Richardson is a biologist with the Florida Panther National Wildlife Refuge, U.S. Fish and Wildlife Service. Funding for this work was supported by the Naples Orchid Society and the Florida Panther National Wildlife Refuge, U.S. Fish and Wildlife Service.

Khan S, Klein-Banai C, Yoshida, K. Restroom Water Reduction Potential at an Urban University. *Sustainability Journal of Record*. 2016; 9: 6: 295–304. doi:10.1089/sus.2016.29073.sk. (University of Illinois at Chicago)

A water audit was conducted at University of Illinois at Chicago (UIC) campus buildings to help evaluate the potential to conserve water and save the university money. These buildings are unique in many different aspects and together are a good representation of an urban university infrastructure. Data was collected by performing a water audit on faucets, urinals, toilets, and showers and suggest it is necessary to upgrade the majority of the fixtures to meet at least the federal and EPA standards. In one scenario of an audit of a university building, the payback was found to be less than two years with a yearly savings of $72,000 and 9.4 million gallons of water per year. Cynthia Klein-Banai is associate chancellor for sustainability and adjunct assistant professor of public health. Kate Yoshida is program coordinator in the Office of Sustainability. As a junior, Khan worked from June 2015 to April 2016 on the project. He graduated in May 2017 with a BS in civil engineering. This project was supported by a UIC sustainability fee that was awarded to Khan.

Mooring, SR, Mitchell, C, Burrows, NL. Evaluation of a Flipped, Large-Enrollment Organic Chemistry Course on Student Attitude and Achievement. *Journal of Chemical Education*. 2016; 12: 93: 1972–1983. doi:10.1021/acs.jchemed.6b00367. (Georgia State University)

The study examined students' attitude and achievement in large enrollment, flipped organic chemistry courses. The results showed that there was a statistically significant improvement in A and B grades and a decrease in failure/withdrawal rates for the flipped course. The results showed a statistically significant increase in students' emotional satisfaction and intellectual accessibility for the flipped course compared to those for traditional lecture courses. This work demonstrates that the flipped course model can be adopted for challenging, large-enrollment courses. Suazette Mooring is an assistant professor of chemistry. Chloe Mitchell was a voluntary undergraduate researcher from 2014 to 2016, working on this particular study in 2016. She is currently a medical student at Mercer University. Nikita L. Burrows earned her PhD in chemistry from Georgia State University in 2017. The research was funded by the University System of Georgia, Complete College Georgia STEM Innovation Grant, which was awarded to Mooring.

Luttamaguzi J, Eslami A, Brooks DM, Sheybani E, Javidi G, Gabriel PM. Using Simulations and Computational Analyses to Study a Frequency-Modulated Continuous-Wave Radar. *International Journal of Interdisciplinary Telecommunications and Networking*. 2017; 9:1: 38–51. doi: 10.4018/ijitn.2017010104. (NASA Goddard Space Center)

This paper describes a method for simulating Frequency-Modulated Continuous-Wave (FMCW) radar. FMCW radar system simulations are an example of a real-world application, invested in rich mathematical/physical content that exercise these competencies. Unlike conventional radars that operate in the time domain, FMCW radars operate in the frequency domain. Spectral and phase analyses are required to infer range and the range resolved velocity of meteorological targets such as rain or drizzle. Jamiiru Luttamaguzi is a faculty member in the Department of Mathematics and General Sciences at Prince Sultan University in Riyadh, Saudi Arabia. Akbar Eslami is a professor in the Department of Technology at Elizabeth City State University. Dwayne Brooks was a mathematics student at Elizabeth City State University and a 2012 NASA intern at NASA Goddard Space Center during this project. Currently he works for a company in Hampton, VA. Ehsan Sheybani is assistant professor of information systems and decision science and Giti Javidi is assistant professor of information technology at the University of South Florida Sarasota-Manatee. Philip M. Gabriel works at General Ana-

lytics in Wolfville, Nova Scotia, Canada. This research was supported by a NASA–Science and Technology Institute for Minority Institutions grant.

Walters LA, Webber JA, Jones BA, Volker CL. Taking a Break: The Relationship between Ambient Temperature and Nest Attendance Patterns of Incubating Carolina Chickadees (Poecile carolinensis). *Wilson Journal of Ornithology*. 2016; 128: 4: 719–726. doi: 10.1676/15-115.1. (Northern Kentucky University)

We investigated the incubation behavior of female Carolina Chickadees using remote temperature data loggers to obtain an extensive, continuous sample of incubation recesses, or off-bouts. We found that as ambient temperature increased, off-bout duration increased while off-bout frequency decreased. This study provides new information about the incubation behavior of this species and helps clarify the complex influence of temperature on the tradeoff between investment in offspring versus self-maintenance for intermittently incubating birds. Lindsey Walters is an associate professor of biological sciences. Three undergraduate students participated in this research during summers 2012–2014: Cassie Volker, Brittany Jones, and Jackie Webber. Volker earned a M.S. from Florida Atlantic University and is now employed at Northern Kentucky University. Jones is a veterinary student at Lincoln Memorial University. Webber is a senior biology major. This study was funded by Northern Kentucky University's Center for Integrative Natural Science and Mathematics (Walters, Jones), a Greaves Undergraduate Summer Fellowship (Volker), and the National Science Foundation (Webber).

Hines JM, Eason JJ, Siebert MR. One Lump or Two? A Plurality of Pathways in Gold(III)-Catalyzed Cyclization Transforming Propargyl Acetates to a Carene-like Bicyclo[4.1.0]heptane. *Organometallics*. 2017; 36: 4: 920–926. doi: 10.1021/acs.organomet.6b00946. (Missouri State University)

The bicyclo[4.1.0]heptane substructure, featured in a number of natural products, is economically formed via gold(III)-mediated cycloisomerization. We used quantum chemical calculations to evaluate multiple pathways that gold(III) could take in the creation of the final product. We found that two pathways are very close in energy, which, in terms of the conventional undergraduate curriculum, would make them difficult to differentiate between. However, relative turnover frequency calculations indicate that a single (cyclization first) pathway dominates. Matthew R. Siebert is an assistant professor in the Department of Chemistry. Jeremy Hines is nearing completion of a master's degree and is seeking admission to a PhD program. Jesse Eason received her bachelor's degree from Missouri State University in spring 2014 and works as a technical writer. This work was supported by XSEDE (grant number TG-CHE150070) as well as Missouri State University's Graduate College, College of Natural and Applied Sciences, and the Department of Chemistry.

Hinsa-Leasure SM, Nartey Q, Vaverka J, Schmidt MG.Copper Alloy Surfaces Sustain Terminal Cleaning Levels in a Rural Hospital. *American Journal of Infection Control*. 2016; 44: 11: 195–203. doi: 10.1016/j.ajic.2016.06.033. (Grinnell College)

This study demonstrated that patients in rooms with high touch copper alloy surfaces are exposed to substantially fewer bacteria than patients in rooms with standard surfaces. It also highlighted the ability of copper alloy surfaces to maintain bacterial loads at or near cleanliness standards following terminal cleaning of the hospital room. In other words, copper is key to protecting newly admitted patients from contracting infections and is an integral part of an effective infection-control strategy. Shannon Hinsa-Leasure is an associate professor of biology at Grinnell College, and Michael G. Schmidt is professor and vice chairman of microbiology and immunology at Medical University of South Carolina. Queenster Nartey received her BA in biological chemistry from Grinnell College in 2016; she is working in a government lab and is in the process of applying to medical and graduate programs. Justin Vaverka is a medical student at the University of Iowa. Funding for this work was provided by a Grinnell College competitive grant awarded to Hinsa-Leasure.

Bilger D, Sarkar A, Danesh C, Gopinadhan M, Braggin G, Figueroa J, Pham TV, Chun D, Rao Y, Osuji CO, Stefik M, Zhang SJ. Multi-Scale Assembly of Polythiophene-Surfactant Supramolecular Complexes for Charge Transport Anisotropy. *Macromolecules*. 2017; 50: 1047–1055. doi: 10.1021/acs.macromol.6b02416. (California Polytechnic State University–San Luis Obispo)

The present study examined multiscale assembly of poly(3-alkylthiophene)s complexed with various alkyl-chain surfactant architectures in dilute and concentrated solutions. In dilute solutions, the complexes undergo a coil-to-rod transition with an intramolecular mechanism. In concentration solutions, the complexes exhibit an isotropic-to-liquid crystal transition yielding hexagonally ordered microstructures. The sheared films from liquid crystalline phases display a four times faster charge transport along the backbone alignment direction than the perpendicular direction. Shanju Zhang is an assistant professor of chemistry, David Bilger is a senior, Jose Figueroa is a junior, Danielle Chun is a senior, and Thanh Vy Pham is a visiting student in the Department

of Chemistry and Biochemistry at California Polytechnic State University–San Luis Obispo. Morgan Stefik is an assistant professor and Amrita Sarkar is a graduate student in the Department of Chemistry and Biochemistry at the University of South Carolina. Cameron Danesh is pursuing doctoral study at the University of California at Los Angeles, Gregory Braggin is working at LAM Research Corp., and Yashas Rao is a research assistant at the SLAC National Accelerator Laboratory. Chinedum O. Osuji is associate professor of chemical and environmental engineering and Manesh Gopinadhan is an associate research scientist at Yale University.

Dozier H, Perry, J. Androids Armed with Poisoned Chocolate Squares: Ideal Nim and Its Relatives. *Mathematics Magazine*. 89: 4: 235–250. doi: 10.4169/math.mag.89.4.235. (University of Southern Mississippi)

The authors describe two new combinatorial games. The first, Ideal Nim, both generalizes the well-known game Nim and its relative Chomp, and provides a recreational perspective on some important ideas of commutative algebra; for instance, the fact that the game is guaranteed to end is equivalent to Dickson's lemma, a well-known fact of commutative algebra. This relationship leads to a game-based proof of Dickson's lemma. The second game, Gröbner Nim, is really a variant of Ideal Nim that illustrates Buchberger's algorithm to compute a Gröbner basis. The authors conclude by describing the relationship between Gröbner Nim and polynomial rings. John Perry is an associate professor of mathematics. Haley Dozier worked on the project from 2013 to 2014 and presented her work at the annual meeting of the LA/MS Section of the Mathematical Association of America. She graduated from University of Southern Mississippi in 2015 with a major in mathematics, completed a master's degree in mathematics at the university, and is pursuing doctoral-level study in computational science at Southern Miss. The work was supported by an Eagle SPUR grant from the Drapeau Center for Undergraduate Research at the University of Southern Mississippi.