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Putting Undergraduate Research on the Map for Women

At the College of Saint Benedict (CSB), faculty from mathematics, physics, and computer science launched a program in fall 2009 aimed at both attracting more women to those disciplines and retaining them once they enrolled. With support in the form of a nearly $600,000 grant from the National Science Foundation, the college created a student cohort-based program called MapCores, (Mathematics, Physics, and Computer Science Research Scholars).

CSB is a private liberal arts college that enrolls 2,000 traditional college-aged women. It shares an academic program and faculty with Saint John's University (SJU), a primarily undergraduate institution that enrolls 1,850 men. The two institutions share single academic departments in every discipline and have identical academic calendars and degree requirements. All students take classes together on both campuses, but live on separate residential campuses with separate student life and development programming. The unique structure of CSB and SJU allows our institutions to focus on issues that pertain to one gender in particular.

Yet even in an environment that keeps gender issues front and center, the educational and professional choices of our students mimic national trends. Women in mathematics, computer science and physics currently account for 26%, 17% and 8% of the majors, respectively. Despite the small proportion of women who graduate in these majors, the women who do are very successful. They attend graduate school within their disciplines and occasionally in other disciplines and find excellent employment in high-tech firms.

The MapCores program exploits CSB's unique educational environment as a means of providing controlled inoculation against, and exposure to, the societal and environmental pressures that discourage women from pursuing careers in mathematics, physics, and computer science. It is a model that can be replicated in typical coeducational college environments.

The program objectives of MapCores are threefold:

- Increase women's participation and persistence in the fields of mathematics, physics, and computer science
- Include women as junior members of the scientific community
- Strengthen women's academic confidence and interest in the targeted disciplines

Making Connections Via the Cohort Model

CSB has significant experience and success in using the cohort model to enhance students' learning and to support high-achieving student populations who might be at risk in the traditional liberal arts environment for reasons other than their academic and intellectual aptitudes. At present CSB supports six cohort programs, all of which have rich academic and co-curricular programming provided by a team of faculty, staff, and students. It was with this deep institutional knowledge, experience, and commitment that CSB embarked on MapCores.

Research has shown that "supportive learning communities" are essential in creating a successful program for intellectual development (Margolis and Fisher 2002). In particular, women-only groups in STEM (science, technology, engineering, and mathematics) disciplines have higher GPAs and more confidence than their peers in coeducational classrooms (Hurt Middlecamp and Subramanium 2001). Studies of women's persistence in science strongly assert that the kind of cohesiveness inherent in the MapCores program will increase women's persistence in the targeted disciplines (Hurt Middlecamp and Subramanium 2001; Margolis and Fisher 2002).

The MapCores curriculum builds on the solid foundation of our coeducational program; yet it is deeply enhanced by a focus on those curricular and co-curricular characteristics that increase positive outcomes for women in science and mathematics.

Recruiting for MapCores

Students learn about MapCores in a variety of ways. Broad outreach activities about MapCores include featuring it in the "Financial Aid and Scholarships" brochure mailed to female high school seniors who make inquiries to the college; listing a MapCores scholarship on the financial aid section of the admissions website; and generating

MapCores Scholars Becca Simon, left, and Michelle Hromatka discuss how to build a motherboard in the Problem Solving Seminar.

community awareness of the program through local and regional media outreach. A MapCores program page was created and can be located through the A-Z Index of the college's website, as well as through links from the relevant departmental pages.

Admissions representatives stay apprised of the program through their liaison to MapCores faculty members. Program and scholarship information is communicated to prospective students during college fairs, high school visits, students' visits to campus, and through conversations with counselors, teachers, and parents. They also target any student who expresses an interest in mathematics, physics, computer science, or pre-engineering classes in our admissions recruitment software. These students' interest levels in CSB range from low (we purchased their name from a student database or testing company) to high (they have applied or been accepted).

Any student who expresses interest in the targeted disciplines receives an introductory letter that provides an overview of the MapCores program and directs students to confirm their interest by completing a form on our website. After the general college application deadline in December, all accepted students' applications to CSB are sorted by intended major and GPA/ACT score, as designated in the MapCores criteria. Our students have had an average GPA of 3.7 and average ACT score of 30.

In fall 2010, the first year of active recruiting for what is actually the second cohort of MapCores participants, 974 recruitment letters were sent to students who expressed interest in the relevant disciplines. They were also sent an e-mail with a link to the online application form. We received 44 responses. Qualified candidates also were identified from the general pool of applicants, even if they did not complete the "interest" form, giving us a total of 116 potential scholarship applicants.

CSB invited 85 of these 116 students to interview for MapCores scholarships. We aim for 16 scholarships with 11 supported by the NSF. Approximately 50 students followed through with the invitations and were interviewed. Over half of these students were also Trustee Scholarship candidates, the most prestigious merit-based scholarships that CSB awards ($16,000 scholarships renewable up to four years). Each candidate for both scholarships was interviewed by one of the investigators involved in MapCores. Offers of MapCores scholarships were made to approximately 27 candidates, and a cohort of 18 students eventually was enrolled.

For the third cohort, recruited for fall 2011 admission, 973 letters were mailed, 86 students were invited to interview, 49 accepted interviews, 26 offers were made, and 18 women accepted the scholarship for fall 2011.

Each MapCores scholar receives a $6,000 scholarship that is renewable up to four years. The costs associated with the first cohort are being borne completely by CSB. The NSF grant funds 11 of the 18 scholars in the second cohort and CSB funds the remaining seven scholars. The NSF grant funds the third cohort, and we hope to secure continued support for subsequent cohorts.

To remain eligible for MapCores, women are required to:

- be enrolled full-time at CSB
- enroll in and complete the courses required by the program
- maintain satisfactory progress (at least a C average) toward a major in mathematics, physics, applied physics, computer science, numerical computation, or pre-engineering

Members of the second-year cohort–Laura Nierengarten, Whitney Radil, and Marie Meyer–make minor adjustments to light sensors on their robot in preparation for robot races during their weekly Problem Solving Seminar.

Mentoring and Support Lead to Retention

Mentoring and support activities that are conducive to retaining women in the disciplines are built into the MapCores program through curricular enhancements (Hurt Middlecamp and Subramanium 2001; Kahveci, Southerland, and Gilmer 2008; Margolis and Fisher 2002).

A three-tiered approach to mentoring and support starts with the faculty. MapCores women receive career and course advice from faculty members during the scholarship interview process, and the support will continue throughout the four years of the program. The second tier of support arises from the cohesive group formed by members of the cohort. The third tier of support is cross-cohort. Women from different cohorts of MapCores participants are "scaffold" mentors for each other, reaching across class years to lend support through organized meetings of the two cohorts in courses and co-curricular activities.

While all CSB/SJU students take the First Year Seminar (FYS), all first-year MapCores women benefit from a specially-designed honors section called the Nature and Practice of Science. The FYS has been the heart of our liberal arts curriculum for over 30 years, with the goal of enhancing students' skills in writing, reading, critical thinking, discussion, oral presentation, information literacy, and research. The MapCores FYS emphasizes readings and discussions about scientific topics.

The honors section for MapCores women adds a forum that addresses societal and environmental factors that create a barrier for women entering the STEM disciplines. It exposes them to opportunities to think like scientists and, perhaps most importantly, develops additional social support networks among the women and faculty members. In addition, this section of the seminar is team-taught by faculty representing each of the MapCores disciplines.

Much research has demonstrated the importance of female role models in encouraging women to major in STEM fields. The representation of women faculty in mathematics, physics, and computer science at CSB/SJU mirrors national trends: two women out of 12 faculty members in mathematics, one of seven faculty members in physics, and one of five faculty members in computer science. CSB and SJU have emphasized the importance of recruiting women faculty in these disciplines, however, with fifty percent of on-campus interviews and job offers extended to women during the last several searches.

During the second year of the program, MapCores women take an all-female problem-solving seminar, in which they are exposed to interesting problems generally not found in regular classes. For example, the scholars may program light sensors on robots to distinguish between color values and follow a line. They write computer simulations of simple ecosystems, learn the probability and statistics related to mass extinction, and conduct experiments with double-pendulums comparing computational models with reality. Hands-on activities like those have been shown to develop spatial reasoning and lead to both better performance and increased interest in mathematics and science (Baenninger and Newcombe 1995). Because women frequently lack practice in solving problems with hands-on

components, the purpose of the problem-solving seminar is to provide women with a supportive environment in which to develop their confidence in understanding, operating, and manipulating mechanical devices. The problem-solving seminar also increases students' STEM self-efficacy, (their confidence in their ability to do science) which in turn increases their persistence in the STEM disciplines. Second-year MapCores women are expected to present their findings from the seminar to the first-year MapCores women to facilitate cross-cohort mentoring.

The third year of the program is a research seminar, where the students work on open-ended problems—developed by the faculty—that utilize their knowledge from our targeted disciplines. For example, MapCores scholars could apply chaos theory to population growth in local ecosystems or use variations in GPS measurements to study changes in the ionosphere.

In the first three years of MapCores, seminars are designed to foster the personal connections between students and faculty members that many female science and mathematics majors need in order to persist in their majors (Seymour 1995), primarily by providing many informal opportunities for women to seek advice and support from faculty. The seminars also help maintain the supportive cohort that was formed in students' first year in the program.

Career opportunities are addressed throughout the seminars so that students develop an appreciation for the variety of career paths available to STEM majors.

MapCores women will complete an honors senior thesis or project in collaboration with a faculty member during their fourth year in college and in the program. Students who complete summer research projects are encouraged to continue those projects for their senior-year work. The cohort meets weekly to present ideas, brainstorm about each other's research topics, and present partial results related to their research. Students present at CSB/SJU Scholarship and Creativity Day, an annual event that recognizes and honors the achievements of more than 400 student-scholars engaged in independent creative work or research projects. We also expect MapCores women to present at student conferences or academic conferences in the disciplines.

By completing a senior thesis or project, students apply the problem-solving, communication, and research skills developed in their regular and MapCores coursework to a project they find intellectually interesting, thus functioning as junior members of the scientific community. Work on this sustained, integrative capstone experience also increases women's academic self-confidence and their interest in the targeted disciplines.

Evaluating MapCores

Faculty members from the targeted disciplines want to gather as much information as possible to improve existing assessment techniques and increase the persistence of all students in mathematics, physics, and computer science. To that end, Pamela Bacon, a CSB/SJU psychology professor who studies how beliefs influence academic achievement, has collected data on attitudes, beliefs, and interests from MapCores participants and relevant comparison groups each year through electronic surveys. The control group consists of both men and women who are studying our targeted disciplines. We are in the process of comparing the MapCores students' results with these other students in order to assess the value of the program.

For initial assessment, the survey was administered to 17 first-year MapCores women, five first-year female students planning to major in STEM disciplines who were not part of MapCores, and 15 first-year male students planning to major in STEM disciplines.

The assessment plan was organized around the project's three objectives.

(1) For example, to measure whether the program is increasing women's participation and persistence in the fields of mathematics, physics, and computer science, we hypothesize that compared to non-MapCores participants:

- A higher percentage of MapCores students will take at least one course from the relevant disciplines in the second semester of their first and second years in college.
- A lower percentage of MapCores students will withdraw from a course in the relevant disciplines in their first or second year.
- A higher percentage of MapCores students will graduate in four years with a major or minor in the relevant disciplines.

- A higher percentage of MapCores students will pursue graduate training in a relevant discipline.

To assess these outcomes, we have begun to work with the registrar's office to obtain enrollment information and data on majors and minors pursued.

(2) To assess whether MapCores women are acting as junior members of the scientific community, we will determine whether several hypotheses are correct. These include hypotheses that these young scholars will be able to solve and present their solutions to increasingly complex scientific problems; will be able to critique research presentations and journal articles in the targeted disciplines; and will be able to develop, conduct, and publicly present the results of an independent research project. We also hypothesize that MapCores women will have a strong understanding of career opportunities in the relevant disciplines and that an increased percentage of students in the program will take part in summer research programs compared to non-MapCores students.

Assessment of students' progress in problem solving skills will be based on their presentations and their critiques of the presentations of others in the seminars. Periodically, students attending the research talks will be asked to complete a written evaluation of the talks, and their responses will be coded to evaluate the complexity of the critiques. Students' knowledge of career opportunities in the relevant disciplines will be assessed using the survey mentioned above. Data relevant to participation in summer research programs also will be collected.

(3) To measure whether the program is strengthening women's academic confidence and their interest in the targeted disciplines, we will assess whether the MapCores scholars demonstrate increased scores over time on measures of STEM self-confidence, social support, self-esteem, and incremental theories of intelligence, and intrinsic goals, as compared to female STEM majors who are not in the MapCores program.

We will also compare MapCores participants to non-MapCores women majoring in STEM disciplines on a measure of interest in mathematics, computer science, and physics over time. We expect to find increased student awareness of the issues facing women in the relevant disciplines over the course of the program and increased positive reactions to women in science among MapCores students over time, compared to STEM female majors who are not in the MapCores program.

During the first two weeks of the fall semester, all students taking Calculus I and Calculus II complete a battery of questionnaires. Any MapCores students who have tested out of calculus also take this survey. The survey provides baseline information about the students' attitudes, interests, and beliefs at the start of the program. Portions of the survey are administered at least once a year to all MapCores students and also to women in the targeted majors who are not part of the program.

First-year MapCores students also write a graded in-class essay, at the beginning of the fall semester and again at the end of the spring semester, in which they are asked to describe what they think makes women less likely to pursue careers in mathematics, computer science, and physics. These essays are coded to determine the degree to which students learned about gender issues related to science during the first-year seminar (FYS) class. This essay will also be required during the MapCores students' final capstone course.

CSB completed the second year of the program in spring 2011, so we have yet to measure and assess overall program outcomes. We have made some assessment in the following areas, however.

Mentoring. Research suggests that women in science classes need to feel connected to others. The MapCores emphasis on developing mentoring relationships with three faculty members during the first-year seminar (FYS) is one way we are addressing this. MapCores women report feeling that they had more mentoring than the non-MapCores students. FYS also allows the MapCores women to develop relationships with each other, which may help them feel connected in their classes. MapCores women try to take their major classes with each other for this very reason. MapCores women also report feeling less lonely than non-MapCores students, which could be due to the strong sense of community developed in the special honors section of the FYS.

Research participation. By making the senior research project a required element for all MapCores women, the program ensures that students do not avoid this challenging opportunity due to lack of confidence. Moreover, to complete a senior research project, MapCores women must participate in research opportunities over the summers after their sophomore and junior years. In summer 2011, five sophomore MapCores scholars conducted research at CSB/SJU with faculty; one had an internship in computer science and two attended Research Experiences for Undergraduates programs, which is very unusual for our students after their sophomore year. The remaining three students participated in research at CSB/SJU. While we do not have summer research as a requirement for any, we strongly recommend it.

Normally in mathematics, for example, we tend to have just one to three students per year who volunteer to do an honors senior research project. All other students do the capstone course that consists of reading mathematics papers and doing presentations on what they have learned. The increased involvement in research by MapCores Scholars earlier in their academic careers demonstrates that we are improving the students' confidence and subsequent participation as junior members of the scientific community.

After recalibrating light sensors on their robots several times, the race is on. From left to right, Becca Simon, Jessica Solfest, Katelin Weiers, and Laura Nierengarten momentarily forget the science and get fired up about their robots' performance in the race.

Lessons Learned Thus Far

CSB completed the second year of the MapCores program in spring 2011, so we have yet to measure and assess overall program outcomes, as we noted above. We have, however, identified opportunities for improvement in our recruitment and programming.

Narrowing the pool. Most MapCores participants selected based on the interview process satisfy program requirements. Identifying which students to bring to campus for interviews has been refined during the last three recruitment cycles. For example, creating an online statement-of-interest form on the MapCores webpage and sending it to college applicants who express interest in the relevant disciplines helped reduce the potential candidate files from around 150 to about 50. Nearly all of those interviewed were, therefore, serious about the program.

We also discovered that the selection process is best completed by faculty members who are immersed in MapCores. While faculty from within the three targeted disciplines were asked to conduct interviews in years one and two of the program, their input was not as helpful as that of faculty members who actually worked with MapCores students. This year, faculty intimately involved with MapCores conducted all of the interviewing. While more time was spent interviewing, faculty members believe they have identified the very best candidates, who eventually received scholarships for year three.

Students' ACT and SAT scores aid in choosing MapCores students, but we have found they are not enough to determine a student's motivation and ability to persist in the program. The kinds of questions we ask during interviews are, we believe, much more useful. We ask about the students' reading, their experience exploring intellectual matters on their own, and the reason for their passion for one of the disciplines.

Becca Simon, class of 2013 and a MapCores Scholar, seated in one of our computer science labs at Saint John's University.

Q&A with a MapCores Scholar

Second-year student Becca Simon, class of 2013, learned about MapCores from her admissions counselor at the College of Saint Benedict. She entered college intending to major in mathematics, but the MapCores program introduced her to new ideas, including a new major. She was interviewed by Heidi Everett.

Interviewer: What is it about MapCores that you have found most beneficial?

Simon: My first semester (when I didn't know anyone), the program introduced me to classmates in my math and computer science classes as a sort of built-in study group. Since then, I have become close to my fellow participants, and we still study together. Having three faculty advisors has also been an amazing resource. They funnel information and opportunities our way, as well as serve as a go-to resource for questions we may have in another class.

Interviewer: Have your perceptions about women and science changed since your participation in MapCores?

Simon: My perceptions about women in science largely have not changed; I know that I am going into a male-dominated field, and there will be struggles.

My chosen major has changed. MapCores exposed me to computer science, which won me over. I am now a computer science major with a mathematics minor. My career goals are still not entirely well defined, but my participation in this program has influenced me toward planning to attend graduate school. In the meantime, I am a research assistant in the computer science department.

Interviewer: At this halfway point of your undergraduate experience, what are you most looking forward to in your next two years in MapCores?

Simon: I am most looking forward to getting a clearer idea of what my career goals are and continuing the educational and personal relationships I've built through this program.

Focusing on the FYS (first-year seminar). We believe that it is useful that all of our reading, discussion, and writing in FYS is centered around scientific topics. Also, we have found class "warm-up" exercises involving scientific thinking have both interested the students and made them more aware of how scientists think.

Because the MapCores FYS is team-taught, more time is spent than was expected on coordinating and planning the honors section. Coordinating and planning are further complicated by the fact that our science and mathematics faculty have not taught discussion-based writing courses as often as other faculty have.

Finally, many MapCores women come into the program with no understanding of the sexism and other forms of discrimination that they might face in the sciences. We have some trouble convincing the students of problems that they could potentially face because of sexism. We are doing our best to arm students with the tools to handles such situations, and we are working with a colleague in psychology to improve our approaches to these issues.

Examining attrition. The bonding and support structures inherent in our cohort-based program have helped MapCores women develop good study habits earlier in their college careers than they might otherwise have done. Consequently, they are doing well in their majors. Students in MapCores appear to be more engaged in the classes in their majors than other students. Faculty in the relevant departments have said that they look forward to having MapCores students in their classes.

The few women who have left the program have done so for academic, personal, and financial reasons. Some students' academic interests changed. Other students' financial need impacted their ability to take full advantage of the program. Finally, many students have difficulty adjusting to college life. Our cohort-model has helped students overcome such problems more easily; however, not all of our students have learned to utilize the support systems we have developed.

Our Learning Continues

MapCores builds on the solid foundation of our existing coeducational structure and bolsters it with a focus on the curricular and co-curricular characteristics that increase positive outcomes for women. The overall goal of the program is to attract, retain, and graduate more women in physics, computer science, and mathematics.

Our assessment plan will generate data that will allow us to contribute to the psychological literature on achievement in meaningful ways. We plan to present our findings at conferences in our respective disciplines and plan to maintain a website that we will use to inform our program participants and faculty, prospective participants, broader campus community, and professional colleagues across institutions about the aspects of our program that were successful.

Our program, inspired and informed by our other successful cohort programs, can, we believe, be a model and work equally well for other groups of students on other campuses.

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Kristen Nairn is associate professor of mathematics at the College of Saint Benedict and Saint John's University. She earned her PhD in mathematics from Columbia University in 2003. During her tenure at CSB/SJU, she has advised numerous undergraduate research projects in mathematics and math-dependent fields such as economics and physics. She is the principal investigator for the NSF grant that funds the MapCores project and is an instructor in the program. She also continues to pursue and publish her research in Gauge Theory and Tropical Geometry.

Heidi L. Everett is the director of institutional advancement at St. Cloud Technical and Community College, and the former executive director of advancement communications at the College of Saint Benedict. She has written several articles on communication and marketing strategies, as well as a best-selling book on business principles. She is currently working on her doctorate in rhetoric and technical communications. Her research examines how visitors judge the credibility of websites, especially those of non-profit organizations and small businesses that use free or low-cost content management systems for website development.

Catherine A. Stoch, director of external grants, joined the College of Saint Benedict in 2001. During her tenure at CSB, the external grants office has attracted more than $12 million in external funding. She is a frequent presenter on the grants process both on and off campus. She received her master's degree from the University of Minnesota in 1996.