Engaging Community College Students in University Research

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Abstract

The future competitiveness of the US economy will depend on its ability to attract talent and foster innovation in STEM (Science, Technology, Engineering and Mathematics) disciplines. In this paper, we present our National Science Foundation (NSF)-sponsored undergraduate research internship program, Internships in Nanosystems Science Engineering and Technology (INSET), and discuss our strategies to attract and support the academic advancement of community college (CC) students in STEM fields. In particular, we show that by partnering with CC administrators and faculty, the program has been successful in designing an accessible research immersion opportunity at the university and attracting a large number of underrepresented students. We discuss the results of our program evaluation, which includes long-term tracking of former interns, and which shows that many of the students experienced significant gains in their interest and confidence in obtaining an advanced degree in STEM. We conclude by offering our program as a successful model for university/CC partnerships, which can be implemented at other institutions.

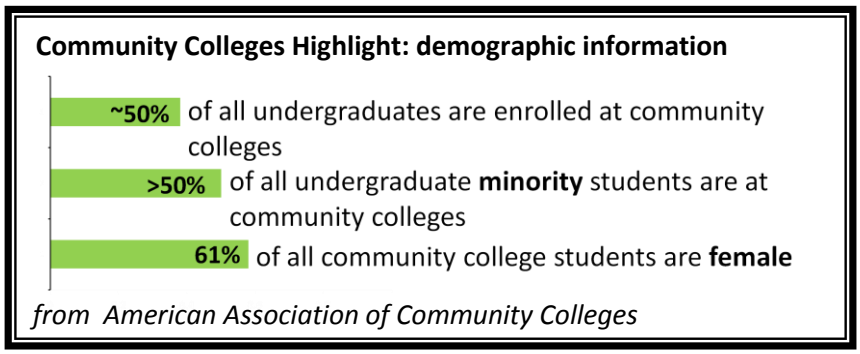
Introduction

In recent years, several reports and surveys have highlighted the need to increase the number of students prepared for careers in STEM fields, considered by all a key factor needed to maintain U.S. intellectual and economic competitiveness [1-4]. However, while the overall number of degrees awarded by four-year institutions in the U.S. has increased, the percentage of bachelor's degrees in STEM fields has fallen to a low of 18% in 2009, from its peak of 24% in 1985 [1]. In fact, in 2008/09, bachelor's degrees in Engineering and Engineering Technologies accounted only for 5% of the 1.6 million total degrees awarded [5,6], much lower than in other countries, such as France (12%) or Germany (17 %) [5,6]. At the same time, a number of recent national reports, including the 2007 report 'Rising above the gathering storm', by the National Academy of Sciences [7], emphasize the critical need to engage underrepresented populations in STEM. Yet, participation and achievement are still uneven across demographic groups, with women less likely than men, and underrepresented minority students less likely than Caucasian students to pursue degrees in STEM [1]. By addressing these disparities, the United States will be better able to fulfill the demand for a high-quality future science and engineering workforce.

Research Experiences for Undergraduates (REU) programs are a proven strategy for introducing students to fields of study they would not otherwise consider and for encouraging them to pursue graduate studies [8-10]. By engaging in research, undergraduate students gain not only an increased appreciation for the research process [8, 11, 12], but the shift from passive to active learning [13-15] and the enhanced research and laboratory skills [8, 12, 16, 17] result in an improved understanding and interest for the discipline. However, in spite of a number of studies showing that early engagement offers the greatest benefits [9, 10, 18], the vast majority (91%) of REU participants are juniors and seniors, as highlighted in a recent extensive evaluation of REU programs by SRI International [9]. The report recommends a shift in this balance through greater engagement of lower division students, as there is a strong correlation between longer research participation and

positive benefits for students, including improved student retention and successful degree completion.

Greater engagement of a diverse population of lower-division students can be achieved effectively by targeting community colleges students (CC). CCs serve a disproportionate number of underrepresented minority, female and nontraditional students, who represent a large pool of potential talent that, due to a misguided perception of its students as being less capable, often remains untapped [19].



In fact, in 2009 in California only 3,100 out of 93,000 associate's degrees awarded were in STEM disciplines. In 2008 only 6,800 out of 46,000 CC transfers to 4-year institutions were in STEM majors. (Note that many CC students in California progress to a transfer without acquiring an associate's degree.) California CCs enrolled 1.5 million undergraduate students in 2008, 39% of whom were underrepresented minorities (URM). This minority enrollment rate was twice that of University of California campuses, which had 20% minorities out of a total enrollment of 173,000 [20].

Program Goals

Our NSF-sponsored REU program, Internships in Nanosystems Science Engineering and Technology (INSET), seeks to address the increasing need for a diverse STEM-trained workforce by attracting and supporting the academic advancement of CC students in STEM fields. The INSET program operates from the University of California at Santa Barbara, a tier-one research university. By focusing exclusively on CC students, INSET effectively promotes early engagement in STEM research, providing opportunities for active learning activities that may increase retention and degree completion, while at the same time drawing a diverse student population.

INSET was designed to expose this traditionally under-engaged pool of students to the excitement of scientific discovery, innovative engineering, and the societal impact of science and technology. This is achieved in part by immersing students in a university research environment, giving them first-hand experience on cutting-edge original research in a discipline of their interest and with the mentorship of a UCSB student just a step or two ahead of them. The CC interns make original contributions to this research while building their skills and, likewise, their confidence. In this way, the main goals of the INSET program lay in increasing successful transfer to 4-year institutions, retention in completing STEM degrees and progression to graduate study. More specifically, our program goals have been to recruit and engage a diverse cohort of CC students into meaningful research activities, to promote their interest in STEM fields and

study, and to encourage their further academic advancement and success through mentorship, increased skills and bolstered confidence.

We argue that key components of INSET's success are: 1) the involvement of CC faculty with a strong interest in promoting student success in all aspects of program planning and execution; 2) the design of activities that provide an encouraging peer group, as well as the level of support that students might need because of lack of confidence and/or unfamiliarity with a university environment, while setting clear goals and high performance expectations. At our campus, the INSET program has been the inspiration for the creation of other CC-university partnerships. We anticipate that INSET might also serve as a successful model for other institutions, who want to encourage and support the advancement of CC students in STEM fields as they transfer to 4-year institutions.

INSET Program Design and Activities

Entering its twelfth year, INSET's success lies in recognizing the importance of involving CC faculty in all aspects of program planning and execution. In particular, CC faculty's input has been key to the design of appropriate student activities, which are non-threatening, motivating, and which address the particular needs of CC students, while providing an environment that offers them greater opportunity to prosper and succeed. CC faculty also play a particularly crucial role in identifying and recruiting high-potential candidates, especially those whose grades may not reflect their abilities and initiative. It is thanks to their encouragement and support that these students, who often lack both self-confidence and role models, are led to view INSET as not only valuable but also possible.

Recruitment

INSET recruitment focuses on CCs throughout California. In particular, we have established strong relationships with four CCs within 60 miles of UCSB: Allan Hancock College, Santa Barbara City College, Oxnard and Ventura Colleges. These colleges have sizable underrepresented minority populations (see Table 1). Typically, two-thirds of all program applicants come from our four partner colleges, and approximately one-third of all applicants are minorities. In fact, particular attention is paid to disseminate information to all of the Mathematics Engineering Science Achievement (MESA) chapters at these CCs. MESA is an academic enrichment program that serves educationally disadvantaged students, with high participating rates of underrepresented minority students. In addition, application information is distributed electronically and through printed brochures to individual CC faculty and staff who are known to take a strong interest in identifying new opportunities for students. Finally, the program coordinator visits each of these four campuses at least once a year to give in-person presentations about the program, and offer guidance on effective application strategies. Past

Table 1: Minority Enrollment at INSET Partner Colleges

Partner Colleges	Hispanic	African Amer.	Native Amer.	Total Underrep. Minority
Allan Hancock College	41.1%	2.6%	0.8%	44.5%
Oxnard College	66.0%	3.5%	0.4%	69.9%
Santa Barbara City College	32.5%	2.8%	0.5%	35.8%
Ventura College	47.3%	2.6%	0.7%	50.6%

2010-2011 Data, from California Community Colleges, Chancellor's Office

interns often join these visits, presenting their research projects and talking about their experience. Their presence has been found to be very beneficial in further increasing students' interest for the program, by offering a role model with whom students can readily identify.

Selection

The selection process has become highly competitive as more students have become aware of the program and our record of success. Applicants apply via an online application and the program typically receives upwards of 120 applications for 16-20 spots. The program has no minimum GPA requirement, and interns who satisfy the prerequisite 4 units of calculus and 12 units of science/engineering classes are selected based on their enthusiasm, maturity and communication skills. Applications are reviewed by a committee and all qualified applicants are interviewed either in person (local students), or via phone or video conferencing (applicants from more remote locations). The final stage of the selection process involves the mentors (UCSB faculty, post-doctoral scholars and graduate students), who carefully review the application materials and interview notes with guidance from the review committee. This step we have found to be crucial in both the success of the placement of the interns in labs, as well as in the recruitment of mentors for the program. Having the mentor take an active role in the selection process personalizes the intern placement, validates the mentor's importance, and helps secure successful placement of each selected intern. In practice, mentors select several applicants and rank them in order of preference, and the selection committee then makes the final decision and placement of each intern.

Summer Research Experience

INSET provides an 8-week research immersion experience for 16-20 students each summer. Activities are designed to provide participants with first-hand experience in scientific investigation in a dynamic, collaborative research environment. A critical point is that all activities are designed to provide the level of support that students might need because of lack of confidence and/or unfamiliarity with a university environment, while setting clear goals and high performance expectations that combat the stereotype of CC students as less capable. The program achieves this by providing a structured experience where, in addition to research activities, there are regular face-to-face meetings among the interns and the staff. Interns are also matched one-on-one with UCSB faculty and graduate student lab mentors, who are expected to introduce them to their research projects, guide them through the initial learning phase, while also providing opportunities for developing critical thinking skills. In-person lab visits by the lead CC faculty mentor within the first weeks of the program ensure that the student and mentor have developed a productive and supportive routine.

Although INSET is intended to be a full-time research experience, the program also focuses on professional development through a variety of workshops and weekly meetings where interns develop their presentation skills. In addition to several social events, including a kick-off BBQ the first week attended by over 120 summer interns and mentors from cross-campus research programs, the INSET interns attend both small group weekly meetings and large weekly seminars, the latter organized for all summer interns on campus.

Each week INSET interns come together in one of two small groups for weekly group meetings with the program staff. The meetings always open with an informal discussion of how things are progressing for the students, an overview of upcoming program events, and conclude with research presentations by each intern. These presentations are slowly built week-by-week as students learn to introduce their topic, present their experimental method, data, analysis, and finally by the end of the program, the conclusions of their work. The mentors also attend these meetings and along with program staff and peer interns, offer constructive feedback on each talk. This process of learning to effectively communicate their research in a supportive and safe environment has been cited by students as one of the most valuable components of the program outside of the research experience. The students gain much confidence through this process and feel quite proud during the final two weeks of the program, when each intern presents a poster at the UCSB Undergraduate Research Colloquium and gives a formal research presentation. This seminar is open to both the campus and local community, and is well attended by UCSB and CC faculty and administrators. On each presentation day, all attendees are invited to an informal luncheon. This not only gives faculty an opportunity to interact with students and mentors, but promotes interaction and planning between UC and CC faculty, staff and administrators and helps build productive working relationships between campuses.

As an additional benefit, all of the interns are invited to submit abstracts to national conferences and present their poster and/or talk at these meetings, thus greatly enhancing their experience in communicating their research to a broad audience and gaining exposure to valuable learning and networking opportunities. The interns' research presentations are all posted on the program website and serve not only as a resource for the intern to cite, but also as a strong recruiting tool for both future intern and mentor cohorts. The weekly research and professional skill development seminars led by UCSB faculty and INSET program staff are the final component to the intern's schedule and engage the students in the diverse local research community and skill development geared at success in college and obtaining advanced degrees.

Role of Mentors

UCSB faculty play an integral role in offering additional learning opportunities throughout the program. In addition to mentoring interns on research projects, faculty lead research seminars and discussions about various topics related to being a scientist or engineer: from applying to graduate school to how research gets funded. They share about their own career path in both these formal discussions as well as informal discussions over lunch in our networking event, Lunch with Faculty. A critical component to building a positive working relationship with faculty has been the program's reputation for attracting motivated and talented students, and its excellent track record in promoting diversity. Another attractive feature is the fact that the program is completely managed by the UCSB Center for Science and Engineering Partnerships (CSEP), a well-established outreach center that provides the infrastructure for running such a program and has no requirements on faculty except for hosting interns in their labs during the summer and providing research projects. As a result, each year several UCSB faculty ask NSF for supplemental funding on existing research grants to support undergraduate REUs, in this case INSET interns, thus allowing the program to further expand and flourish.

Along with faculty, the graduate student and post-doctoral scholar mentors serve as critical role models for the interns as they are closer to these students in age and career position. The participation of graduate student mentors is not only crucial for the success of the undergraduate student research experience, but makes a substantial contribution to the professional development of the graduate students themselves.

Because of the key role mentors play in INSET's success, care is taken to both recruit motivated mentors as well as provide support for the mentors during the 8-week program. During the academic year prior to the program we recruit mentors through email announcements and through a workshop discussing the benefits of mentoring. In preparation for the program we hold a mandatory workshop training session for all mentors where we facilitate discussions about project design and management, intern goals and strategies for effective mentor-intern communication. In addition to the education staff, previous mentors attend and act as facilitators who guide newcomers through this preparation and further develop their own mentoring skills. Key to ensuring adequate support for the mentors during the program is an open-door policy with all the staff that includes one-on-one lab visits, a midpoint all-mentor meeting and regular email correspondence to encourage mentors, answer any questions and mitigate any potential issues should they arise.

Program Evaluation and Outcomes

We define the scope of INSET evaluation by our program goals: to recruit and engage a diverse cohort of community college students into meaningful research activities, to promote their interest in STEM fields and study, and to encourage their further academic advancement and success through mentorship, increased skills and confidence. Real-time monitoring of student performance and progress as well as formative survey data collected from both student researchers and their mentors enables the INSET staff to modify program activities for maximum benefit during the current and future summers. Additionally, summative evaluation and long-term tracking of student progress after they leave the program enables us to identify factors which have contributed the most important and lasting impacts for students. Of particular importance is to determine those ways in which the CC student experience may differ from the more typical undergraduate researcher who is an upper-classman attending a research university. These identified differences not only help to guide program design, but also to identify how important and impactful research experiences can be for CC students, who are often from disadvantaged and/or underserved populations.

Formative assessment of the INSET program focuses on collecting real-time feedback from participants about ways in which activities are successful or could be improved. This includes consulting with CC students, faculty and MESA directors to identify effective recruitment strategies, as well as administering student and mentor surveys regarding the organization, content and appeal of all summer program activities: seminar series, training workshops, colloquia, etc.

Summative assessment at the end of the summer program looks at three main areas to measure the degree of success in attaining student learning and development objectives. First is the development of student research skills, which we evaluate through the students' scientific

presentations/reports, through self-reporting surveys and from mentor feedback. Secondly, we survey students about how the research experience may have changed their attitudes about science and engineering, about how research is conducted, and about students' perceptions of their own interests and abilities to pursue more research and/or careers in STEM fields. Lastly, we also examine the mentoring relationships, by surveying students and their mentors to determine if the program is providing adequate and appropriate mechanisms for promoting successful mentorship.

Long-term tracking of students after they leave the INSET program enables us to assess how the research experience has impacted student's future academic and career choices. We track students by asking them to complete an annual survey which requests them to provide information about their academic progress, degree completion and possible advancement to graduate study. We ask them to tell us about their engagement in further research opportunities, in professional conferences, about presentation and publication of their research work, as well as engagement in any mentoring, teaching or leadership activities. We also ask them to report on their current and future career plans. Perhaps most importantly, we ask them to self-report on how they feel that their participation in INSET has influenced their subsequent choices and interests. These anecdotal reports help us to assess the truly personal impacts of the INSET experience.

Diversity and Demographics

The INSET program has shown consistent success in recruiting diverse cohorts of CC students. Between 2002 and 2012, 843 students applied, and 189 students were accepted to participate, leading to an admission rate of ~22%. Of the participants, 41% were female, 44% were members of an under-represented minority, and 3% were students with disabilities (see Figure 1).

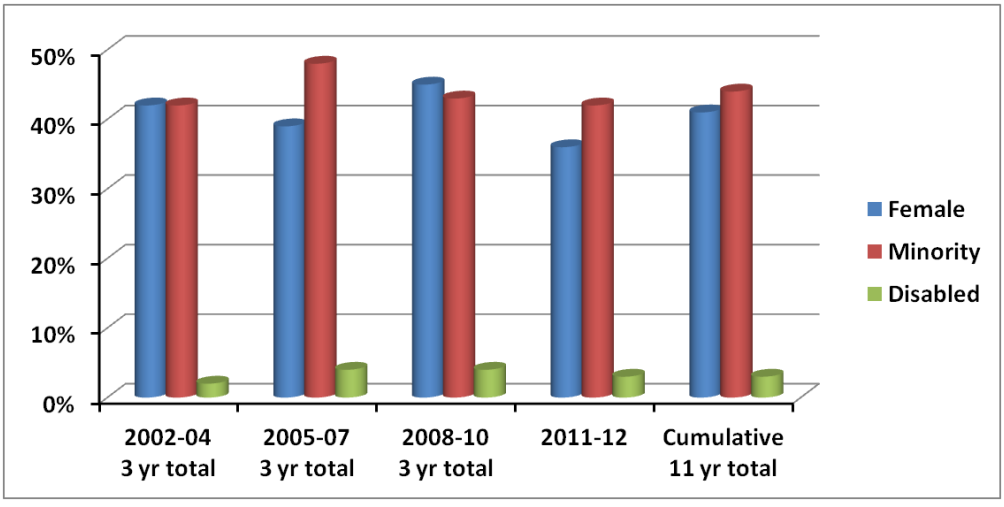


Figure 1 Demographic information for INSET interns for the period 2002-2012, describing percentage of women (blue bars); ethnic minorities (red bars) and disabled (green bars) students.

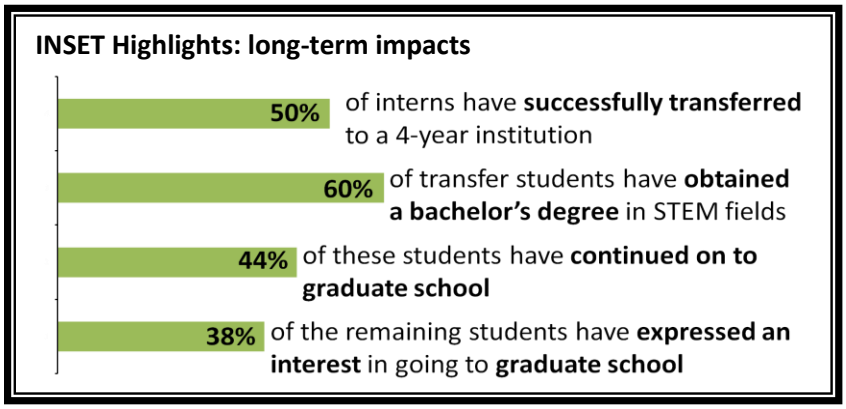
Short Term Impacts on Students and Mentors

Although the REU program lasts only 8 weeks each summer, the INSET student interns consistently perform high quality research, as evidenced by their final presentations, which are made available to the research community and public on the Center for Science and Engineering Partnerships website (CSEP - http://csep.cnsi.ucsb.edu/cc/inset), as well as their contributions to conference presentations and peer-reviewed publications. For the years 2002-2011 approximately half of all INSET interns personally presented their work at state and/or national level conferences, including the Southern California Conference for Undergraduate Research (SCCUR), the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), and the Annual Meeting of Sigma Xi, the National Research Honor Society. A number of these students have won awards for best poster presentations (4 at Sigma Xi and 6 at SACNAS). For the years 2002-2009, 9 students were contributors to papers/posters presented by their graduate student mentors at national conferences, 14 students have co-authored published articles or book chapters, and 5 students have been named in the acknowledgments of publications written or co-written by their graduate student mentors. Based on this data, it is not surprising that each year, some interns are asked by their lab to extend their research participation, either as paid or volunteer positions from several months to several years.

In program-end surveys, students report similar gains in learning, confidence and skills as is typical with most undergraduate researchers in STEM [9, 21]. Students report more confidence in their research, communication and presentation skills and increased confidence and interest in STEM courses, careers and research. They identify several areas of new learning that they feel are their most important gains: hands-on lab skills, new theory and real-world applications, working in collaboration with a research team, developing new problem solving skills and the ability to work independently. They also indicate that among their most important experiences was learning from and working with their graduate students and faculty mentors, as well as becoming enveloped in the university research culture and community. And lastly, they report a significant increase in awareness, interest and confidence in pursuing graduate study.

Finally, for the mentors similar gains and outcomes are observed. Through their mentorship experience, graduate students make improvements in several areas, including communication, teaching, project design and planning, supervision, and time management. They also gain awareness of equity and access issues for underrepresented and under-served groups. These are exactly the types of skills and experience which are stated as important for the professional training and development of the science and engineering workforce [22]. Additionally, mentors report that by explaining their research in simple terms and in the context of a ‘bigger picture’, they gain a better understanding of their own research and goals. An unexpected contribution has been that interns have sometimes discovered ideas, methods, and results that have previously eluded the research mentors. This is perhaps, at least in part, a result of the fresh perspectives that CC students bring to research due to their being less entrenched in a particular research area or to their life experiences, as many CC students are returning students who are seeking new careers, are parents, or have served in the military, etc.

Long-Term Student Impacts



Long-term tracking of 132 interns that participated in the program between the summers of 2002 and 2009 demonstrates that INSET interns continue to succeed academically after completing the program, and a majority of them continue to participate in research. Among the participants, 120 have already successfully completed their transfer to a 4-year institution, and 70 have completed a bachelor's degree, all but one within STEM disciplines. From this group of college graduates, 31 students have progressed onto graduate study, including 13 students who are currently enrolled in STEM doctoral programs; 27 additional students expressed an interest in pursuing graduate work. We anticipate that the numbers of students pursuing graduate work will increase over time, since there is a natural lag due to the time for transfer to 4-year institutions and the time for completion of a bachelor's degree.

The importance of the INSET experience in shaping students' perspectives on pursuing opportunities for graduate school and STEM careers is also demonstrated by their responses to the surveys distributed as part of our long-term tracking efforts:

> *"The most valuable experience that I obtained from INSET was that I was able to see the environment in which graduate students work. I saw what they were expected to do and how they interacted with professors, other students and post docs. Most importantly, I saw how passionate and knowledgeable they were about their fields of study. This experience was very encouraging and it made me more certain that being a graduate student was my next goal."*

> *"The INSET program had a very positive impact on my interest in pursuing graduate study. I learned a tremendous amount about the technical aspects of working in a laboratory and the type of life I can expect when I to become a graduate student."*

> *"INSET showed me what real research is all about and how practical and interesting it can be. I showed me that I can compete with people who entered a 4-year university right after high school and convinced me that I could get into and be successful in a graduate school."*

> *"Before INSET my interest in science was relatively vague and unfocused. I feel very lucky to have been assigned to a project that has been so fascinating to me. I have been able to get a real taste for graduate level work, and it is a welcome change from the day-to-day class time and homework associated with my undergraduate studies. I love learning and genuinely enjoy my classes, however there is something very fulfilling about personally doing "real science" in a laboratory as opposed to simply reading about theoretical science based on*

what others have done. INSET has opened the door to my experiencing what it really means to be a scientist."

Former interns report a desire to give back to their home campuses and communities, and 47% of them reported participating in leadership and teaching roles related to STEM education and careers (e.g., acting as peer-mentors, tutors, officers for student clubs and professional chapters, and teachers in science and mathematics to K-12 students). Four students reported that they founded new student clubs or foundations that serve disadvantaged and underrepresented populations.

Conclusions

We have presented an overview of INSET, our NSF-sponsored undergraduate research internship program, and discussed our strategies to attract and support the academic advancement of CC students in STEM fields. Our program goals have been to recruit and engage a diverse cohort of community college students into meaningful research activities, to promote their interest in STEM fields and study, and to encourage their further academic advancement and success through mentorship, increased skills and confidence. We have shown that by partnering with CC administrators and faculty, the program has been successful in producing a long-running model that is meeting these goals and attracting growing numbers of students, including a large number of underrepresented students. We have discussed the results of our program evaluation, which includes long-term tracking of former interns, and which shows that many of the students experienced significant gains in their interest and confidence in obtaining an advanced degree in STEM: gains that translate into successfully transferring to their selected four-year institution, completing their degree and continuing on to graduate programs. We hope that by presenting our crucial findings and successful strategies, INSET might be used as a model at other institutions for university/CC partnerships.

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