

Increasing the Number of Homegrown STEM Majors: What Works and What Doesn't

Abstract

University of Nebraska – Omaha (UNO) and Metropolitan Community College (MCC) have recently completed a five-year NSF STEP project to increase the number of homegrown STEM graduates. The overall project has been quite successful, and the numbers of degrees granted has increased. However, some strategies have worked much better than others. Among the successful strategies are close collaboration between the two institutions, support for walk-in tutoring, early undergraduate research, bridge scholarships, and adult learner scholarships. Conversely, targeting incoming freshmen as recipients of scholarships is not only expensive, but also found to be relatively ineffective at increasing the number of STEM graduates.

Introduction

The United States is not producing enough homegrown college graduates in the STEM (Science, Technology, Engineering and Mathematics) areas, and the National Science Foundation (NSF) is making a massive effort to remedy this situation. In particular, NSF established a program called STEP (STEM Talent Expansion Program) to give two- and four-year colleges and universities in the United States a financial incentive to attempt any and all reasonable strategies to increase the number of American

students studying, and graduating in, the STEM areas.

The University of Nebraska at Omaha (UNO) and Metropolitan Community College (MCC) received a grant, “UNO and MCC STEPping Together,” in the first round of competition in 2003 and kicked off a joint five year program in May 2004.

The NSF STEP Request for Proposals makes it very clear that STEP's emphasis is on effectiveness, not innovation. In other words, it is not necessary to do something new and different, just to do things that work to increase the number of STEM graduates. Our basic approach has been broad and inclusive, based on the assumption that we would have the greatest success if we reached out to large numbers of potential STEM students. UNO and MCC are the two largest postsecondary institutions in Omaha, NE, a growing metropolitan area, and are not competing with each other to attract students. For these reasons, it is natural for us to work together to promote STEM education.

Now one year beyond the end of the five year grant funding, we believe that we have achieved overall success as indicated by the following “bottom line” data (Table 1):

During this period the number of UNO STEM graduates grew by 38% while the total number of UNO graduates grew by 32%. Overall biology (including bioinformatics) made big gains in graduation rates; chemistry and mathematics made modest gains; and computer science, geology and physics were essentially flat. These

outcomes by discipline track closely with the degree of UNO faculty and departmental participation in STEP activities, as will be seen in the discussion to follow. Having the PI and a co-PI from mathematics and chemistry, respectively, increased the awareness of STEP in these two departments but having much more faculty enthusiasm for STEP in biology made an even bigger difference. The pipeline from MCC into UNO STEM majors also expanded significantly during the grant period and, based on the work established in this program, this particular success will be more evident in the years to come. These gains were made possible by a variety of activities, some of which were much more effective than others. In this article, we describe those strategies that we have found most effective – as well as those that we have found to be relatively ineffective – for the benefit of other institutions that have the same goal of increasing the number (and enhancing the educational experiences) of STEM majors. We begin by describing our efforts to develop collaborative relationships between both institutions and faculty, because a) these actions established the context required for the development and implementation of other strategies, and b) we believe that the importance of establishing collaborative relationships is often overlooked.

Collaboration between institutions

One of our greatest successes and one that has facilitated the development

Key words: collaboration, bridge, scholarship, walk-in, tutoring, early undergraduate research

Table 1: UNO STEM Graduates by Academic Year

Discipline	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Biology/Biotech	57	66	83	80	117	103	108	94	98
Bioinformatics	0	0	0	1	0	4	2	4	6
Chemistry	6	3	4	7	6	6	8	9	8
Computer Sci	56	63	67	63	61	50	53	42	52
Geology	0	4	3	1	4	3	5	1	3
Mathematics	18	20	18	27	19	28	26	23	26
Physics	5	2	1	0	4	4	6	3	5
Total STEM	142	158	176	179	209	198	208	176	196
Total UNO	1400	1459	1550	1604	1730	1779	1862	1944	1876

and implementation of all project activities is the collaboration that we have established between our two institutions – one a four-year university and the other a metropolitan area community college. We have benefited from an existing articulation agreement between the two institutions that allows students to transfer credit for essentially all academic (as opposed to vocational) courses from one institution to the other. As a result of this existing agreement, during the first year of the project we were able to create six new pre-STEM associate degrees in biology, bioinformatics, chemistry, math, and physics at MCC with full transferability to UNO and then start identifying prospects for these majors. This task was performed by a full-time MCC STEP Coordinator who, after three years of being employed by the STEP grant, has now become an MCC student advisor for the STEM areas. MCC students were able to apply for MCC Bridge Scholarships (awarded by MCC) when they got within 50 hours of completing their associate pre-STEM degree. Students also became eligible for UNO Bridge Scholarships (awarded by UNO) if they transferred into a STEM major at UNO, regardless of whether they had first completed a degree at MCC. The first MCC Bridge scholarships were awarded during the second year of the STEP grant. The number of new MCC Bridge scholarships awarded (Table 2) continued to grow right up until the grant funds ran

Table 2: MCC Bridge Scholarships Awarded by Academic Year

	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
scholarships awarded	4	15	22	19	42	11

out in Summer 2009 (source: MCC Office of Institutional Research).

The effort to publicize the new pre-STEM degrees and the availability of Bridge Scholarships attracted many more associate degree-seeking students to STEM areas of study. The data below indicate that the numbers of MCC students seeking associate degrees in STEM areas increased substantially during the period in which these efforts took place (Table 3).

Finally, in addition to increasing the number of MCC students who declared pre-STEM majors, the program has also been successful at increasing the number of MCC students who transfer into STEM majors at UNO (Table 4).

However, it was not only the existing articulation agreement that allowed us to create new degree programs so quickly. From the outset, we took steps to foster genuine collaboration between institutions at the faculty level by utilizing techniques that have been shown to promote effective team processes and outcomes (see Levi, 2007, for an overview). Project goals were largely task-oriented. Agendas and relevant documents were circulated prior to monthly meetings of project personnel in order to allow participants time to formulate ideas and questions regarding project activities.

Additionally, meeting summaries that described the discussions and identified tasks to be completed, as well as the persons responsible for completing them, were circulated shortly after the meetings.

Perhaps more important, however, was the quality of communication among project personnel. Meetings often included graduate students as well as faculty and administrators from both institutions. Participants were encouraged to contribute information, expertise, and ideas and to express both supportive and dissenting points of view. Criticisms were task- rather than person-focused. Indeed, after participating in their first meeting, two industrial/organizational psychology graduate students expressed to the evaluator how impressed they had been with the quality of the discussion. We believe that, as a result of these efforts to promote effective communication and collaborative relationships, our work has been both quantitatively and qualitatively better than it might otherwise have been.

Walk-in Tutoring and the Math-Science Learning Center at UNO

At UNO, one activity that worked well was grant-supported

Table 3: MCC declared pre-STEM majors by academic year

	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Biology	22	20	53	73	96	62	95	98
Chemistry	8	12	12	20	20	13	20	21
Comp Sci	180	203	197	246	307	235	256	304
Engineering	115	169	150	194	172	111	188	184
Math	9	8	18	19	14	9	26	20
Physics	2	5	9	10	12	8	8	8
TOTAL	336	417	439	562	621	448	593	635

Table 4: UNO STEM majors who transferred from MCC
(with 25+ MCC hours and counted in...)

Discipline	Spring 2003	Spring 2004	Spring 2005	Spring 2006	Spring 2007	Spring 2008	Spring 2009	Spring 2010
Biology, Biotech	20	28	29	42	49	56	62	66
Chemistry	2	3	6	5	6	9	7	11
Comp Sci, Bioinf	28	28	22	23	24	23	22	21
Engineering	32	33	40	47	50	49	59	57
Environ Science	6	4	5	4	7	8	6	13
Geology	1	2	1	3	1	1	1	4
MIS	50	45	30	27	25	26	22	24
Math	3	3	7	9	9	10	14	16
Physics	0	0	1	3	5	6	3	5
TOTAL	142	146	141	163	175	188	196	217

walk-in tutoring. It started in Fall 2003 as Math/Physics Walk-in Tutoring by employing upper level math and physics majors. This service proved to be very popular, and student use grew steadily each year. In Fall 2005, chemistry began its own separate walk-in tutoring. In 2006, the University of Nebraska system provided permanent funding (with the NU Foundation contributing one time renovation costs) for a Math-Science Learning Center (MSLC). A key factor in its successful launch was a concerted effort to achieve faculty buy-in. All of the science (and math) departments were involved in the initial planning, and a PhD faculty member (in chemistry) was hired as the Director. The MSLC opened its doors in Fall 2007 and now, in Fall 2010, it is averaging 1700 visits per week and employing about 30 student workers for a total of 200 hours per week. Furthermore, there are now more than ten Facilitated Study Groups each semester to complement most

freshman and sophomore level courses in biology, chemistry, mathematics, and physics. More specialized areas, such as engineering, statistics and mathematics education, are supported by their own tutors. Furthermore, tutors are selected and given initial training directly by faculty, which contributes to even more faculty buy-in. The MSLC has developed huge visibility at UNO and has established working relationships with other general education outreach efforts on campus, such as the First Year Experience and the NASA Resource Center as well as NU system-wide programs including the Young Nebraska Scientist Initiative. Although it is only three years old, the MSLC already plays a central role in STEM education on the UNO campus for STEM majors and non-majors alike. Thus, our initial STEP supported walk-in tutoring efforts have been not only sustained but also greatly expanded through the NU supported Math-Science Learning Center.

Institutional sustainability is a fundamental goal of the STEP program.

Early Undergraduate Research (EUR)

We had much success promoting early undergraduate research, but there also were some problems. The quality of student participation was inconsistent, and the quantities of students choosing to participate varied greatly. In some ways, this aspect of the program successfully appealed to a broad spectrum of STEM faculty. It involved a total of 19 faculty, including two at MCC, in a total of 40 different projects over six summers. However, a single biology professor had 65 students in seven different projects over six years; this accounts for about 1/3 of the total of 194 student participants. Most research groups had three to four students each. Additionally, 126 students from 18 projects were in biology alone, and this accounts for well over half of the total number of students reached.

UNO faculty in chemistry, geology and physics were mostly unresponsive to direct requests for participation. On a more positive note, as of Fall 2010, 169 of the total of 194 participants are either STEM graduates or still STEM majors, which means that 87% of the students involved have been successfully retained.

Another problem was to encourage faculty to pitch the projects to “early” undergraduates and following up by successfully recruiting students at this level. Upper classmen, i.e., already committed majors, typically jump at the opportunity for research experience and were likely to be more assertive in expressing interest to the faculty sponsor. In order to address this problem, tuition reimbursement for the last two summers was given only to students with pre-freshman, freshman, or sophomore class standing. Upper classmen were able to participate but were not eligible for tuition reimbursement. A very promising modification was used for the last two summers. Seven years ago, UNO set up a Dual Enrollment (DE) program with Omaha area high schools whereby high school students are able to earn UNO course credit for AP courses taken in high school. Most academic areas are included, in particular, the STEM areas of biology, computer science, mathematics, and physics. The high school students pay nominal tuition for DE credit, a portion of which goes to the academic departments to use for DE “enhancement.” In Spring 2008, all STEM DE students were invited to gain additional college credits by participating in a Summer 2008 project. Much interest was generated: 22 high school students participated in three different biology projects and nine high school students participated in a mathematics project. DE enhancement funds were used to help pay the costs, i.e., faculty stipends and student tuition. Besides keeping the focus on the age group that is most likely to result in

the recruitment of more STEM majors, a DE focus has the potential to help institutionalize our work by providing it with at least a partial funding base. Biology continued this DE focused activity in Summer 2009 but with less success.

Scholarships

Finally, we have provided scholarship aid as a way of encouraging students to pursue STEM majors. As mentioned above, this is working very well with respect to Bridge Scholarships for MCC students, including those who transfer into STEM majors at UNO. Each such student received up to \$500 per quarter at MCC and \$1000 per semester at UNO. For (STEP’s final) Spring 2009 semester, eight former MCC students received these scholarships at UNO. Incredibly, as of Fall 2010 there has been no attrition for Bridge scholars at UNO. All 15 of the former MCC students who received one of these scholarships is still pursuing (or has graduated with) a STEM major at UNO.

Our efforts to use scholarships to recruit STEM majors directly out of high school were much less successful. Over a four-year period, we gave out about 20 STEP Scholarships at \$1000 per semester to incoming freshmen at UNO who declared a STEM major. Unfortunately, there was a high rate of attrition for these students. Of the 18 scholarships awarded in Fall 2004, only 11 recipients persisted through three years (i.e., two scholarship renewals). As of Fall 2010, nine are STEM graduates and two are continuing STEM majors. Of the 19 students who received these scholarships in Fall 2005, only nine persisted as STEM majors after four years. A common occurrence is for these students to transfer into related fields such as pre-pharmacy, pre-nursing, and pre-therapy. Such students do not obtain STEM degrees at UNO. For

these reasons, STEP scholarships for entering freshmen were phased out. A more compelling scholarship option, Adult Learner Access Scholarships (ALAS), modeled on a University of Toledo scholarship by the same name, was pursued instead. ALAS provided limited financial aid to adult students, aged 24 or older, who declared STEM majors (and who, therefore, didn’t have to be recruited) and who have good academic records. Each scholarship recipient received a tuition waiver of \$450 per semester, which is the approximate cost of resident tuition for a 3 credit hour course at UNO. ALAS could be renewed for one additional semester but only when enrolled in a STEM course required for the declared STEM major. The simple technique of notifying all eligible ALAS prospects each semester led to as many as fifty students applying for and receiving ALAS tuition waivers per semester. ALAS was awarded to 125 different individuals between Spring 2006 and Summer 2009 when funding ceased for our STEP grant. In Fall 2010, 118 of the ALAS recipients have either graduated with a STEM degree or are still pursuing a STEM major. This represents a successful retention rate of 94%.

Providing outreach to adult STEM majors fits well into a collaborative effort between a metropolitan university and a community college, because both institutions serve many adult students. Moreover, a STEM Retention Study, performed during Fall 2007 by the UNO Psychology Department, provides an additional justification for offering this option to older students. This study showed that, for a total of 4536 STEM majors of record since Fall 2005, the 48% who were still STEM majors in Fall 2007 had an average age of 22.83, while the 22% who had dropped out of UNO had an average age of 25.61. Thus older STEM majors are more likely to drop out than younger STEM majors, although we

are not sure why this happens. This is one reason to give older adult STEM majors (financial) encouragement. For another reason, consider the following, Table 5:

This table includes both the engineering program on the UNO campus, which is administered under UNL, and also Management Information Systems (MIS) which was added to UNO STEP activities near the end of the grant period. One reason for expanding STEP activities to include MIS is that the female percentage of MIS graduates is more than double the female percentage for CS graduates. Therefore, efforts to attract more females into IT are more likely to succeed by concentrating on MIS. A second reason for including MIS in STEP activities is that it is, as indicated in an earlier table, the single most popular STEM major for MCC students who transfer to UNO. The table shows, first of all, that the percentage of female STEM graduates is relatively constant. However, it also shows that the steady overall trend for female STEM graduates can be attributed primarily to an increase in the percentage of female biology graduates. Without biology, the percentage of female STEM

graduates has actually decreased, with the biggest decreases occurring in computer science and engineering. An ALAS program can have an especially beneficial effect on non-biology female STEM majors, particularly important because females tend to have higher rates of attrition from STEM majors and are under-represented in STEM careers (Ceci, 2007). Indeed, STEM careers may be perceived, especially by women and ethnic minority students, to conflict with family goals and responsibilities (Blickenstaff, 2005; Diekmann, Brown, Johnston & Clark, 2010; Hurtado, Han, Saenz, Espinosa, Cabrera & Cerna, 2007). Financial support that lessens the negative perception of the pursuit of such careers may thus be one way to help retain women and ethnic minority students in non-biology STEM majors.

Evaluation

In addition to the collection and analysis of the data reported here, we have sought to understand various social and psychological factors that may affect our efforts to recruit and retain STEM majors. Psychology faculty and students have, for example, assessed students' perceptions of the

social climate in STEM courses. These data indicated that, although perceptions were generally positive, white male STEM majors feel slightly less isolated in their majors than at UNO in general, whereas just the opposite is true for ethnic minority and female STEM majors. We are continuing to investigate ways to minimize feelings of isolation among ethnic minority and female STEM majors, but this information has already influenced our thinking about the design of the Math-Science Learning Center, specifically in the context of tutor training and the makeup of the faculty oversight committee. All of these studies, including the retention study referred to above, are available on the UNO STEP website (<http://unomaha.edu/step>).

Conclusions

A broad-based collaborative effort between a metropolitan university and a comprehensive community college can achieve substantial gains by "STEPping" together to promote STEM education. Such a collaborative effort is most readily implemented by establishing an equitable relationship between partners so that both gain by working together. The community

Table 5: University of Nebraska at Omaha
Undergraduate STEM Degrees Awarded to Female Students at UNO from 2001-2002 to 2009-2010 AY

	2001-2002			2002-2003			2003-2004			2004-2005			2005-2006		
STEM Disciplines	Total	Female	%	Total	Female	%	Total	Female	%	Total	Female	%	Total	Female	%
Biol & Biotech	57	39	68.4	66	39	59.1	83	54	65.1	80	56	70.0	117	70	59.8
Bioinformatics										1	1	100	0	0	
Chemistry	6	2	33.3	3	1	33.3	4	1	25.0	7	5	71.4	6	3	50.0
Computer Sci	56	13	23.2	63	12	19.0	67	4	6.0	63	8	12.7	61	5	8.2
Engineering	78	7	9.0	89	11	12.4	107	13	12.1	126	16	12.7	118	12	10.2
Geology				4	1	25.0	3	1	33.3	1	0	0	4	2	50.0
Mathematics	18	10	55.6	20	9	45.0	18	5	27.8	27	7	25.9	19	7	36.8
Mgmt of Info Sys	102	32	31.4	78	22	28.2	77	26	33.8	90	23	25.6	68	18	26.5
Info Assurance															
Physics/Astron	5	1	20.0	2	1	50.0	1	0	0	0	0		4	0	0
TOTAL	322	104	32.3	325	96	29.5	360	104	28.9	395	116	29.4	397	117	29.5
Total w/o Bio	265	65	24.0	259	57	22.0	277	50	18.0	315	60	19.0	280	47	17.0

TABLE 5 Continued:

	2006-2007			2007-2008			2008-2009			2009-2010		
STEM Disciplines	Total	Female	%	Total	Female	%	Total	Female	%	Total	Female	%
Biol & Biotech	103	72	69.9	105	58	55.2	94	49	52.1	98	51	52.0
Bioinformatics	4	1	25.0	2	1	50.0	4	3	75.0	6	2	33.3
Chemistry	6	4	66.7	8	2	25.0	9	3	33.3	8	6	75.0
Computer Sci	50	2	4.0	53	1	1.9	42	3	7.1	52	1	1.9
Engineering	118	4	3.4	121	14	11.6	154	24	15.6	125	15	12.0
Geology	3	0	0.0	5	2	40.0	1	0	0.0	3	1	33.3
Mathematics	28	6	21.4	26	5	19.2	23	11	47.8	26	5	19.2
Mgmt of Info Sys	53	7	13.2	48	9	18.8	46	7	15.2	41	8	19.5
Info Assurance							1	0	0.0	1	0	0.0
Physics/Astron	4	1	25.0	6	0	0.0	3	0	0.0	5	1	20.0
TOTAL	369	97	26.3	374	92	24.6	377	100	26.5	365	90	24.7
Total w/o Bio	266	25	10.0	269	34	13.0	283	51	18.0	267	39	15.0

college gains by providing its students with additional educational options. The university gains by increasing an already sizable pool of potential new students. More importantly, however, the diverse students we serve have benefitted from the efforts of faculty and administrators who worked across institutions and disciplines in an effort to improve educational opportunities and experiences and thereby increase the number of STEM graduates. For additional information on this project again see the STEP website: <http://unomaha.edu/step>.

References

- Blickenstaff, J.C. (2005). Women and science careers: Leaky pipeline or gender filter? *Gender and Education*, 17, 369 – 386. Doi: 10.1080/09540250500145072
- Ceci, S. et al (2007). Why aren't more women in science: Top researchers debate the evidence. Washington D.C.: American Psychological Association.
- Diekmann, A.B., Brown, E.R., Johnston, A.M. & Clark, E. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering and mathematics careers. *Psychological Science*, 21, 1051-1057. Doi: 10.1177/0956797610377342
- Hurtado, S., Han, J.C., Saenz, V.B., Espinosa, L.L., Cabrera, N.L. & Cerna,

O.S. (2007). Predicting transition and adjustment to college: biomedical and behavioral science aspirants' and minority students' first year of college. *Research in Higher Education*, 48, 841 – 887. doi: 1007/s11162007-9051-x

Levi, D. (2007). Group dynamics for teams (2nd ed.). Los Angeles: Sage.

University of Toledo (2011, January 14). University of Toledo University College Webpage. Retrieved from http://www.financialaid.utoledo.edu/university_college.htm

University of Toledo (2006, December 13). Directions: University of Toledo. Retrieved from http://utoledo.edu/offices/president/docs/directions_dec.doc

Jack Heidel, PhD, is Professor and Chair, Department of Mathematics, University of Nebraska at Omaha, Omaha NE 68182, to whom correspondence concerning this article should be sent: jheidel@unomaha.edu.

Hesham Ali, PhD, is Dean of the College of Information Science and Technology at UNO.

Bernadette Corbett, PhD, is Professor of Chemistry at Metropolitan Community College, Omaha NE 68103.

Jenny Liu, PhD, is Associate Director of Institutional Research at UNO.

Bradley Morrison, MS, is Dean of Mathematics and Natural Sciences at MCC.

Michele O'Connor, MA, is former Dean of Mathematics and Natural Sciences at MCC.

Dana Richter-Egger, PhD, is Director of the Math/Science Learning Center and Assistant Professor of Chemistry at UNO.

Carey Ryan, PhD, is Professor of Psychology at UNO.

Acknowledgements: the authors wish to thank Mr. David Reyes who started out as the full-time MCC STEP Coordinator in June 2004 and later became a full-time academic advisor at MCC but continues to help us with ongoing STEP data collection. We also wish to thank Mr. Jason Gerlt, MA Psychology, who was the STEP GTA Scholarship Coordinator from January 2004 – August 2007. Finally we wish to thank Ms. Marilyn Liebsch, Academic Coordinator in Mathematics from January 2006 – August 2009, for help in keeping track of the many different strands of STEP activities.

This project was supported by NSF STEP Grant DUE-0336462.