Advances in Engineering Education

FALL 2019

The Middle Years in Engineering: An Effective Transfer Partnership Drives Student Success in STEM

MARCIA LAUGERMAN
Drake University

DES MOINES, IOWA

AND

DIANE ROVER
STEVE MICKELSON
MACK SHELLEY
Iowa State University
Ames, Iowa

ABSTRACT

Increasing the number of transfers and graduates in engineering who start at community colleges (CC) requires strategic partnering between institutions. Reflecting on the results of a five-year partnership between a large, multi-location CC and a large four-year university, we present the goals, conceptual framework, specific results, and best practices for developing and sustaining STEM partnerships to increase the number of transfers and graduates in engineering. There were four foundational practices to this partnership: (1) inter-institutional collaboration, (2) creating a CC engineering orientation course, (3) developing an engineering admissions partnership program for CC students, and (4) data collection and analysis for informed decision making. The specific foundational practices described in this paper are part of a larger effort to increase the persistence of CC transfers in engineering by creating or enhancing a transfer-friendly environment, a community of practice through partnerships, greater awareness about engineering and engineering careers, student-faculty interaction, and new datasets for research and evaluation. Results of the partnership include a notable increase in the number of pre-engineering students, the number of students participating in the engineering admissions partnership program, the number of students transferring to the university, the number of transfer students participating in a learning community, and an increase in first-year retention rates of CC transfer students in engineering.

Key words: Community colleges, Persistence in engineering, Engineering transfer, STEM success

INTRODUCTION

Recently, the President's Council of Advisors on Science and Technology (PCAST) reiterated the need for more science and engineering graduates in the United States, suggesting that the nation will need about one million more science, technology, engineering, and mathematics (STEM) graduates over the next ten years than the country will produce (PCAST 2012). Of the five specific recommendations, one focuses entirely on creating partnerships between two- and four-year institutions to diversify and increase this number of graduates. The report states that these connections should "provide authentic STEM experiences for community college (CC) students on the four-year campus and allow students to develop relations with faculty and the college or university community to ease the potential transition from a two-to-four-year institution or to provide advanced experiences for students who do not pursue a four-year degree" (PCAST 2012, p. 14). The present article describes in detail what program practices were successful in increasing the number and persistence of CC transfers in engineering for one such funded partnership between a large multi-location CC and a large research university.

For a CC transfer student in engineering, the middle years involve surviving the transfer process, adapting to the university environment, and applying foundational mathematics and sciences skills in more advanced coursework. The transfer student doesn't have time to explore different engineering majors, has not built a community of support, and has no record of success at the new institution. This paper reports the creation of a transfer-friendly and student-success environment through partnerships and collaboration, which increased persistence in engineering for CC transfer students. The Student Enrollment and Engagement through Connections (SEEC) project was initiated with support from the National Science Foundation (NSF) Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) grant to increase the number of students (U.S. citizens or permanent residents) receiving associate or baccalaureate degrees in established or emerging fields within STEM. The SEEC project was a comprehensive and collaborative project between Iowa State University (ISU) and Des Moines Area Community College (DMACC) to increase the number of pre-engineering students at DMACC, the number of students from DMACC who successfully transfer and persist in the College of Engineering (CoE), and ultimately the number graduating with a bachelor's degree in engineering at ISU. Since the programs created for DMACC would also be offered to other Iowa CC students, the project would ultimately increase the success of all Iowa CC transfer students. The STEP grant made it possible for extensive collaboration and data sharing between the institutions. Success strategies focused on learning communities, academic advising, student engagement and success, and career awareness. Over the grant period, engineering enrollments and the number of students graduating increased substantially at both institutions.

The SEEC project was informed in part by research from the National Academy of Engineering (NAE) *Changing the Conversation* report (2008), which provides results of a research-based effort to develop and test new, more effective messages about engineering. The overall conclusion of the report is that the public image of engineering and engineers must appeal to the optimism and aspirations of students and must be all-inclusive. In the past, the image of engineers has been focused mostly on majority populations and messages have emphasized the preparation, especially in mathematics and science, necessary for engineering careers. Recently, an NAE report, *Messaging for Engineering: From Research to Action* (2013), supports efforts by the engineering community to communicate more effectively about the profession and those who practice it. It concluded that to interest young people from all backgrounds; the new messages must cast engineering as inherently creative and concerned with human welfare, as well as emotionally satisfying, thereby appealing to their desire to develop hands-on solutions to problems that can make a difference in the world and improve people's lives.

The Purpose of this Paper

This paper reflects on the SEEC project practices and summarizes results and recommendations from an inter-institutional collaboration focused on upward transfer. A subset of the recommendations presented is backed with statistical evidence. The SEEC project goals, conceptual framework, specific project results, and best practices serve as key messages for others developing STEM partnerships. We share what worked in this successful partnership to increase the number of transfers and graduates in engineering who started with the CC pathway. Of the many successful SEEC practices, this paper focuses on four that are foundational to the success of CC transfers to engineering: (1) inter-institutional collaboration, (2) creating a CC engineering orientation course, (3) developing an engineering admissions partnership program for CC students, and (4) data collection and analysis for informed decision making.

The goals of these practices are to (a) engage transfer students while still at the CC and (b) create messaging for academic advisors, faculty, and students based on student participation and persistence data that summarize relevant findings of this research study. Increasing the number and persistence of CC transfers in engineering includes creating a transfer-friendly environment, a community of practice through partnerships, greater awareness about engineering and engineering careers, student-faculty interaction related to educating and training the engineer of 2020 (National Academy, 2004), and new datasets for research and evaluation. In addition to providing findings through data analysis, the results determine distinctive strategies to increase the participation and persistence of CC transfers in engineering.

Background

Nearly half of all undergraduate students enroll at a CC sometime during their education (Handel and Williams 2012). For the 2010-11 academic year, 56% of all Iowa students who completed a degree

at a four-year institution had previously enrolled at a two-year institution (National Student Clearinghouse Research Center 2012). Despite the large numbers of potential new enrollments at four-year institutions that CC students could provide, it has been estimated that only 25–35% of CC students actually complete the transfer process (Handel and Williams 2012). CCs are vital to the health of our education-driven economy by providing students for four-year colleges and universities (American Association of Community Colleges 2013).

The CC pathway is also a way to recruit and support women in engineering. CC programs historically have higher representation among underrepresented groups, such as female, minority, first-generation, and lower-income students (National Academy of Engineering, 2005). Research supports the assertion that, compared to men, women scientists and engineers are more likely to have attended a CC at some point in their academic career (Tsapogas 2004). However, despite being over-represented in CCs, Sullivan et al. (2012) found that transfer students in engineering were less likely to be women. Strengthening the pathway to an engineering degree through collaboration and support of transfer has the potential to increase both the number of engineering graduates and the diversity of these graduates.

CC graduates also have a positive impact on the local and state economy. In the 2015 annual report, Des Moines Area Community College (DMACC) reported that 95% of their graduates (in all majors) live and work in Iowa (DMACC, 2015). Students from CCs who complete bachelor's degrees may be more likely to stay in-state once they have finished their education, especially in high-demand fields such as engineering. A SEEC study at ISU (Laugerman and Mickelson 2011) found that a significantly higher percentage of engineering graduates who transferred from a CC took jobs in-state as compared to non-transfer students.

However, there are "enduring obstacles to transfer" (Mullin 2012 p. 4) that must be overcome. These include the nonlinear paths that students take through transferring into and out of multiple institutions, dropping out or stopping out, prior college credits, and massive open-online courses (Mullin 2012b). Research indicates that, along with other types of support, CCs would do well to provide more counseling for transfer students (Hagedorn, Moon, Cypers, Maxwell, and Lester 2006; Laanan 2007). Because the process of preparing for transfer and the transition involved is complex, students' chances of transferring and completing a baccalaureate degree are greatly enhanced when two-year and four-year institutions work together to facilitate the process and reduce barriers (Community College Survey of Student Engagement 2007). Most importantly, research shows that creating a culture of transfer is the key component in successful transfer partnerships (Kisker 2007). Creating a culture of transfer begins with partnerships that can raise students' awareness of the opportunities available to them before, during, and after transfer (PCAST 2012). CCs occupy a unique position that enables them to work with K-12 students and administrators, employers, and 4-year institutions of higher education. However, for a transfer partnership to be successful, participants must work to establish a high degree of trust among institutions and the individuals within them (Kisker 2007).

One practice with solid evidence that participation increases retention is the creation of learning communities (LCs) (Taylor, Moore, MacGregor, and Lindblad 2003; Tinto 2006; Tinto 1997; Zhao and Kuh 2004). LCs at ISU (Iowa State University Learning Communities 2012) feature small groups of students who generally take one, two, or three courses together and may live in the same residence hall. Other characteristics involve:

- introduction to university resources
- peer mentoring and/or tutoring
- faculty mentoring
- contact with students who have similar academic goals, and
- career exploration.

Long-term LC data from ISU (Iowa State University Learning Communities 2012) show that, compared to non-LC participants, LC participants' one-year retention rates are 8 percentage points higher, average six-year graduation rates are 12 percentage points higher, and overall student satisfaction and engagement are higher. Also, a higher percentage of students of color participate in LCs (76%) than the overall participation rates (70%) in LCs for all students. The LCs program, which began in 1995 with 407 participants, now has over 5,000 participating students annually.

An important feature of LCs is peer mentoring. Myers, Silliman, Gedde, and Ohland (2010) summarize literature showing that first-year students are more comfortable going to upper-class engineering students rather than to faculty to discuss educational topics, consistent with a number of studies demonstrating that informal relationships and mentoring in a variety of organizational contexts are accepted as important to integration and retention (Jacobi 1991; Ragins, Cotton, and Miller 2000). Further, student-student relationships have been recognized as the largest influence on student satisfaction with several college environments, with student-faculty relationships as the second-largest influence (Astin 1993; Korte and Smith 2007).

In addition to the other obstacles to pursuing an engineering degree, the difficulty of the coursework itself continues to be a major obstacle. Among the external characteristics, the rigor of engineering curricula is cited as one of the most important variables contributing to student attrition, with calculus being the largest obstacle (Zhang, Anderson, Ohland, Carter, and Thorndyke, 2004). Students with a C average or less in calculus have a high probability of leaving engineering (Veenstra, Dey, and Herrin, 2009; Zhang, Min, Ohland, and Anderson, 2006). Whalen and Shelley (2010) found a notable increase in retention and/or graduation achieved by an average increase of as little as one-tenth of a percentage point in cumulative GPA. This suggests that doing what is necessary to improve grades must be the top priority for retaining engineering students.

This background research supports our persistence strategies for engaging CCs and universities in STEM partnerships.

OVERVIEW OF PROJECT

The project started in 2007 with the goals of increasing the overall number of DMACC pre-engineering students, the number of transfer students, the persistence rates of these students, as well as the overall number of engineering graduates.

The Collaborators

DMACC is a public institution and Iowa's largest two-year college. It offers 153 programs, certificates, and transfer degrees, annually serving more than 75,000 credit and non-credit students at campuses and learning centers throughout Central Iowa. DMACC serves a 6,560 square mile area in 22 counties and has a student-to-faculty ratio of 18:1.

ISU is a public land-grant and space-grant research university located in Ames, Iowa. Founded in 1858, ISU is classified as a Research I University with very high research activity (RU/VH) by the Carnegie Foundation for the Advancement of Teaching. A record 36,001 students enrolled at ISU in the fall of 2015. ISU is among the largest engineering schools in the country, producing over 1,155 graduates in 2015 (14th in the nation in 2015, American Society of Engineering Education (ASEE)), and enrolling 7,730 undergraduates in 2015 (7th in the nation in 2015, ASEE).

Demographics of Participants

The SEEC project (2007 – 2012) began by collecting and analyzing an extensive amount of data pertaining to ISU engineering students. The overall goal of the data collection and analysis was to develop standard reports to help administration make programming decisions at ISU, DMACC, and other Iowa CCs that foster transfer student upward mobility in engineering at ISU. SEEC project goals also included increasing the number of engineering graduates including women and minorities, as well as building on the success of LCs in recruiting and retaining engineering students. An initial request to ISU's Institutional Research and Engineering Career Services returned semester-by-semester transcript data. These data were not intended to assess the effectiveness of the SEEC Project, but to develop a baseline of data for CC transfer and non-transfer students. This dataset included 10,441 non-transfer students and 1,191 CC transfer students who entered the CoE between 2002 and 2010, and retention data through 2011.

We also used a subset of the CC data to measure graduation rates in engineering. This subset included 472 in-state CC transfer students admitted to the CoE between 2002 and 2005, which allowed them sufficient time to graduate. The demographic characteristics of these three groups of students are included in Table 1. The demographic characteristics between the groups of students were not statistically significantly different at $p<0.05$, except for the percentage of females, which was 14.7% for non-transfer students compared to 6.8% for CC transfer students.

Table 1. Demographic Percentages of Students Admitted to the College of Engineering (CoE).

Group	*N* Total	Female %(*N*)	Black %	White %	Hispanic %	American Indian %	Asian %	US Citizen %
CC Transfer Students 2002–2005	472	7.0	2.5	77.5	1.3	1.1	5.3	92.2
CC Transfer Students 2002–2010	1,191	6.8	3.4	81.2	1.5	0.8	3.6	92.9
Non Transfer Students 2002–2010	10,441	14.7*	2.6	80.3	2.6	0.3	4.2	91.3

*Statistically significantly different between All Students and CC Transfer Students at $p<0.05$
Notes: The 2002–2005 students are a subset of the 200–2010 data used to calculate the graduation rates.

Retention Rates of Participants

Despite having similar demographic characteristics, three statistically significant retention and attrition rate differences existed between the CC transfer students and non-transfer students. First, a higher percentage of the CC transfer students left the university when they left the CoE. For the CC transfer students, 51.3% had graduated or were still retained in the CoE, 101% had left the CoE but had either graduated or were still retained in non-engineering majors at the university, and 101% left the university when they left the CoE. For the non-transfer students 55.0% had graduated or were still retained in the CoE, 20.4%, had left the CoE but had either graduated or were still retained in non-engineering majors at the university, and 24.6% left the university when they left the CoE.

Second, statistically significant differences existed between CC transfer students and non-transfer students in the one-year retention rates in the CoE, For CC transfer students the average one-year retention rate (over the ten-year history) was 66.0%, compared to the average one-year retention rate of non-transfer students of 73.8%. The two-year retention rates were not significantly different, but the three-year retention rates were significantly different as shown in Table 2.

Table 2. Retention Rate Comparisons for All Engineering Students.

Period	Non-Transfer Students (*n*=10,441)	CC Transfer Students (*n*=1,191)
One-Year	73.8%	66.0%*
Two-Year	60.4%	54.9%
Three-Year	55.2%	44.4%*

*Statistically significantly different between non-transfer and CC at $p<0.05$
Notes: CC=Community College.

Table 3. Retention Rate Comparisons for Female Engineering Students.

Period	Non-Transfer Students (*n*=1,524)	CC Transfer Students (*n*=81)
One-Year	75.4%	46.3%*
Two-Year	61.9%	45.2%*
Three-Year	56.7%	31.1%*

*Statistically significantly different between non-transfer and CC at $p<0.05$
Notes: CC=Community College.

Third, there were statistically significant differences between CC transfer students and non-transfer students in the retention rates for female CoE students. The average one-year retention rate in the CoE for female CC transfer students was 46.3%, whereas the average one-year retention rate in the CoE for female non-transfer students was 75.4%. Similar significant differences existed in the two-year and three-year retention rates between female CC transfers and female non-transfer students in the CoE as shown in Table 3.

In addition to the significant differences in retention rates, there were statistically significant differences in academic performance measures between CC transfer students and non-transfer students. Data comparing First Fall, First Year, and University core-engineering course GPA by admit status show statistically significantly lower GPAs for CC transfer students (see Table 4). Data comparing Mathematics ACT scores and High School GPAs by admit status show statistically significantly lower Mathematics ACT scores and High School GPAs for CC transfer students (see Table 5).

CC transfer student participation in LCs, however, increased retention rates by about 5% per year. LCs became available to transfer students in the CoE in 2005, and the historical data show a 5% higher retention rate for CC students who participated in a LC than for those who did not participate.

Table 4. Admission Status and GPA.

Admission Status	Non-Transfer Students (*n*=9,065)	CC Transfer Students (*n*=1,011)
First Fall GPA	2.72	2.31*
First Year GPA	2.78	2.42*
University BP GPA	2.71	2.32*

*Statistically significantly different between non-transfer and CC at $p<0.05$
Note: not all records of grades were accessible for all students. Notes: CC=Community College, BP=Basic Program in Engineering, GPA=Grade Point Average.

Table 5. Background Characteristics by Admission Status.

Admission Type	Non-Transfer	CC Transfer
Math ACT	28.0 (*n*=9,849)	25.0* (*n*=585)
HS GPA	3.63 (*n*=10,441)	3.24* (*n*=585)

*Statistically significantly different between non-transfer and CC transfer at p<0.05
Notes: HS GPA=High School Grade Point Average, CC=Community College
ACT=American College Testing, HS=High School, GPA=Grade Point Average

Despite higher retention rates for LC participants, low participation rates were measured. Only about a third of CC transfer students participated in an LC, which was a factor the SEEC project sought to improve by the creation of the Engineering Admissions Partnership Program (E-APP).

Foundational Practices

The first foundational practice of the SEEC project was inter-institutional collaboration, which resulted in numerous programming changes and online resources that were developed for CC transfer students (see Appendix). This collaboration correlated with increased retention rates for in-state CC transfer students. Before SEEC, CC transfer students left ISU at higher rates than they did following the initiation of the project strategies.

A second foundational practice was the creation of a CC engineering orientation course. ISU and DMACC created an orientation course, EGR 100, which provides pre-engineering students with a broad overview of the engineering disciplines and general information about the transfer process to a four-year institution. The course brings in guest speakers from ISU's CoE, as well as professionals in industry. Scheduled plant tours give students the opportunity to see engineering in action. Students not only learn about engineering career opportunities but are given information about internships and experiential learning that they could participate in as students. A guest speaker explains behavioral-based interviewing to help prepare students for their interviews. The class also makes a trip to the ISU Engineering Career Fair each semester. Enrollment in DMACC's introductory engineering course increased every year of the project. Since the inception of EGR 100 at the CC:

- Of the original 160 pre-engineering students enrolled at DMACC in 2007, 7% were women, and 5% were members of under-represented minority (URM) groups.
- Of the 467 pre-engineering students enrolled at DMACC in 2012, 17% were women, and 16% were URM.
- Enrollment in DMACC's introductory engineering course, EGR 100, is now available at four sites, to make the courses more accessible, including an urban campus with more URM students.

EGR 100 was originally developed with an emphasis on providing DMACC pre-engineering students who would be transferring to ISU's CoE with information about the transfer process. It now includes more general information about the transfer process to meet the needs of those who will go into engineering at any four-year institution. Broader transfer information includes information about financial aid and ways to finance an engineering education. A course audit is conducted, and a graduation plan is created that encompasses both the student's graduation from DMACC and his or her plan for graduation from a four-year institution. Additionally, information about the differences in culture between DMACC and a four-year institution are discussed to help students make a smoother transition to a larger institution.

The third foundational practice was the creation of an Engineering Admissions Partnership Program (E-APP), designed to improve the navigational success of CC transfer students through connections to the university while still at the CC (Laugerman, Shelley, Mickelson and Rover 2013). E-APP's goal is to increase CC students' engagement prior to coming to ISU and thus increase their retention and graduation rates. These connections include coordinated academic advising, peer mentoring, campus visits, and online social and professional networks. Pre-engineering CC students who sign up for ISU's APP are invited to join the E-APP LC.

One of the features of the E-APP is the online professional network. This site is moderated by transfer peer mentors—former CC students who transferred into engineering at ISU. Here transfer students connect with each other prior to transfer, as well as meet ISU engineering students, faculty, and staff. Peer mentors offer advice based on experience, answer questions, post information about events, and guide discussions. Students are also apprised of on-campus speakers and other general engineering events through the online professional network. E-APP also hosts events throughout the year to bring transfer students to campus.

Within the scope of E-APP, the project has promoted and developed other engineering LCs specifically for transfer students. This was in light of the 5% increase in retention rates for CC students who participated in a LC. LCs are part of a collaborative, connection-based strategy to increase retention among all student segments, with an emphasis on CC students, and was part of the overall strategy of the SEEC project. This is especially important in light of our data collection and analysis, which showed these cohorts of CC transfer students had statistically significantly lower mean GPAs, as well as lower mean Mathematics ACT scores and mean high school class ranks, than the cohorts of non-transfer students who entered the CoE.

The fourth foundational practice was to collect and analyze data for informed decision making for academic advisors, faculty, and students based on performance data that summarize relevant findings of this research study, and to create new datasets for sustainable future research and evaluation. This will be discussed in detail below.

Data Analysis Methods

Numerous descriptive and inferential statistics, including t-tests, analysis of variance, and Pearson's product moment correlation, were employed in our analysis. In addition, a boosted logistic regression model was estimated (Laugerman, Rover, Mickelson, and Shelley 2015) using the Stata software package and the AdaBoost feature (Hastie, Tibshirani, and Friedman 2001). For retention studies, we used course grades and the Kaplan-Meier survival estimator (Kaplan and Meier 1958) and the Wilcoxon, Breslow, and Gehan test for differences between survival curves (Laugerman, Shelley, Rover, and Mickelson 2015; McGready 2006). In addition, we developed a structural equation model (Kline 2011) to explore predictors of completing a BS in engineering for CC transfers (Laugerman and Shelley 2013). The models were estimated using academic variables from both institutions, including grades and number of credits, and controlling for background demographic characteristics.

DISCUSSION OF PROJECT OUTCOMES

The project started in 2007 with the goal of increasing the overall number of engineering graduates, as well as increasing the number of DMACC pre-engineering students and transfer students, and the persistence rates of these students. The project called for an annual increase in the number of all engineering graduates (not just transfers) by 100 per year during the project, to 900 graduates annually by the project's end in 2012. The actual number of all graduates in 2012-13 was 1,013, a 28% increase over the course of the project. In addition, the number of all students enrolled in the CoE increased 58% over the course of the project. These increases exceeded national gains reported by ASEE over the same time period of 19% and 25%, respectively.

Research Findings Based on Statistical Analysis

The fourth and final foundational practice was data collection and analysis for informed decision making. An important result of the SEEC project was a more rigorous data collection and analysis process, as well as systems for monitoring efforts to improve CC transfer student achievement. A major reason for this success was the data sharing that occurred between the institutions, which was initiated by ISU as a result of the SEEC study. Statistical analysis of retention data showed that DMACC CC transfer students enrolled in the E-APP had statistically significantly higher one-year retention rates than non E-APP transfer students. A quasi-experimental study conducted as part of this project (Laugerman, Shelley, Mickelson and Rover 2013) evaluated E-APP. The objective of the study was to determine the efficacy of the E-APP and its interventions, which are measured by increased participation rates and increased university retention rates for E-APP participants.

Table 6. Participation in Engineering Admissions Partnership Program (E-APP) and Retention with Average Mathematics ACT Score for DMACC Community College Transfer Students.

	College of Engineering One-Year Retention	University One-Year Retention	Average Mathematics ACT Score
E-APP Participant	77% (n=52)	90% (n=52)	24.2 (n=33)
Non-E-APP Participant	58%* (n=106)	76%* (n=106)	24.6 (n=47)

*Statistically significantly different between E-APP and non-E-APP at $p<0.05$

The results showed statistically significant improvement in first-year retention rates in the CoE for DMACC E-APP participants, compared to non-participants as shown in Table 6.

Statistical analysis showed correlations between academic success in engineering at ISU and grades in core engineering courses for CC transfer students. Students were able to increase their success by achieving certain levels of GPA. In general, students had statistically significantly higher survival (retention) rates if they achieved at least a B in the core engineering courses, and, once they began at a CC, completed all of the mathematics and physics courses before transfer (Laugerman, Shelley, Rover, and Mickelson 2015).

The highest-influence predictors of completing a BS in engineering for CC transfers were identified using a logistic regression model (Laugerman, Rover, Mickelson, and Shelley 2015). The variables that were statistically significantly related to graduation in engineering were the first-year GPA after transfer and the total core engineering credit hours transferred.

Using the same data, a structural equation model was developed to explore predictors of completing a BS in engineering for CC transfers. The variables that were statistically significantly related to graduation in engineering were: first spring GPA after transfer (assuming a fall semester transfer), first spring credit hours completed after transfer, CC transfer credit hours toward core engineering courses, first fall credit hours completed after transfer, first fall university GPA after transfer, and university engineering core course GPA (Laugerman and Shelley 2013).

Sustainable Outcomes

The SEEC best practices workshop is available on video for the benefit of aiding other inter-institutional collaborations (Iowa State SEEC, Best Practices Workshop, 2013). The workshop was held to share foundational practices with participants from both institutions and other community colleges in the state, and sessions at the workshop reported on progress made in each foundational area of the project. A number of SEEC websites with recommendations for transfer students have been created and sustained since the completion of the project (see Appendix). The holistic approach

of the SEEC project has enabled DMACC and ISU to leverage and support other outreach, scholarship, and retention programs; reach out to elementary and secondary students with the messages of STEM, to encourage students to study engineering; support those who identify themselves as pre-engineering majors; recommend successful navigation strategies revealed as a result of our research; and support pre-engineering students through the transfer process and incorporate them into a successful university experience.

The SEEC project contributed to a transfer-friendly and student-success-focused environment in engineering and pre-engineering. The project created a sustainable inter-institutional partnership in engineering between ISU and DMACC. The SEEC collaboration also contributed to new partnering efforts across STEM areas between the institutions. Data sharing between the institutions was improved through the SEEC study. The resulting changes in educational strategy for CC transfer students demonstrated the value of research and evidence to inform educational practice. Numerous transfer advising materials and communications for and with CC stakeholders have been developed and distributed as a result of this project.

Positive outcomes from SEEC provide lessons that will benefit other efforts to enhance CC student success through similar navigational programs that may be of special support to women and students of color. The SEEC project enabled the intentional creation of successful and sustainable practices for CC transfer, to raise awareness, and to continue to expand the knowledge base of "what works" for recruitment, retention, and placement into engineering careers. In addition, DMACC and ISU have developed extremely user-friendly electronic means of communicating information about transfer options for students.

Further STEM Developments

DMACC continues concerted efforts to communicate with, recruit, and advise students about entering the field of engineering, including two major events.

(1) Discover Engineering Day was conducted for high school (HS) students, with DMACC inviting HS students to come to the DMACC Ankeny Campus and participate in a day of "discovering engineering." The students participated in hands-on engineering-type activities, heard from engineers in the field, listened to an education panel made up of DMACC and ISU faculty, discussed educational strategy in terms of coursework, and experienced engineering activity that promoted upward transfer. Students are invited to participate if they are involved in concurrent courses offered through Project Lead the Way, the United States' leading provider of transformative learning experiences promoting engineering for K-12 students and teachers.

(2) Explore Engineering Day was conducted for current DMACC students, including advice for connecting students with practicing engineers. In addition, DMACC has initiated numerous

developments for STEM students, including establishing a new Associate of Science Degree (effective August 2014) for STEM majors seeking to transfer to earn a Bachelor's Degree and a Celebrate Innovation Week that immerses students and the general public in a variety of interactive projects to promote creative and innovative thought. The intent is to engage students and the public in a focused context outside of their normal studies and lives to help them see both the value and process of innovation.

DISCUSSION OF PROJECT CHALLENGES AND LIMITATIONS

Identifying Pre-Engineering Students

One of the biggest challenges for the CC is identifying the students who are in a pre-engineering track. Prior to the SEEC project, pre-engineering students were identified post-admission by their course-taking patterns, such as enrollment in EGR 100 or in Calculus and Physics courses. Since the completion of the project, DMACC has developed a coordinated process to recruit, identify, and provide outreach to pre-engineering students beginning with admission to the CC.

Disaggregating Transfer Student Data

Separating out CC transfer student data in engineering, from other groups of students admitted to the CoE, presented a number of unique challenges since it had not been done at either institution prior to this study. Data came from multiple sources, including the ISU Office of Institutional Research, ISU's Admissions Office, and the CoE Career Services Office. Tracking of students was difficult, sometimes necessitating transcript-by-transcript analysis. One limitation of the data for this study is that the transfer institution listed is where the student attended most recently and may not be the school from which the student had the most transfer credit hours. It is not unusual for a transfer student to bring credit hours from multiple institutions. Additionally, the study did not consider students who left the CoE and later returned nor those students who started in another college at ISU and transferred subsequently to the CoE. These students constituted a very small percentage of the overall student population.

Limitations

Inherent in this type of study is the imperfection of student transfer data. In our study, the data classified any student as a CC transfer who had taken a course at the CC following high school graduation and preceding any courses taken at the university. This study did not incorporate a minimum number of credits from the CC, and did not take into consideration other CCs a student may have

attended, only the most recent one. Not all of the CC transfer students had background data such as ACT score and high school GPA. This study was limited by the amount of information available from the sending transfer institution. It did not include data about the completion of an associate's degree. It was also limited to information about a select group of transfer students from one state, acknowledging that STEM persistence varies across demographic regions and within ethnic groups, as well as between men and women (Hagedorn and Purnamasari, 2012). Although grades are a quantitative measure of success, we were not able to control for measurement error and for all sources of variability. This study used the final course grades a student received and did not count the number of times a course was repeated, if at all.

CONCLUSIONS AND RECOMMENDATIONS

This paper has reflected on SEEC project practices and summarized results and recommendations from an inter-institutional collaboration focused on upward transfer. The specific foundational practices described in this paper are part of a larger effort to increase the number and persistence of CC transfers in engineering by creating or enhancing a transfer-friendly environment, a community of practice through partnerships, greater awareness about engineering and engineering careers, student-faculty interaction, and creating new datasets for research and evaluation. The goals of these practices were to (a) engage transfer students while still at the CC and (b) create messaging for academic advisors, faculty, and students based on student success data. Studies conducted through the collaborative project offer statistical evidence supporting recommended practices. The video of the best practices workshop which highlights all of the areas that were foundational to the success of the project is available online (Iowa State SEEC, Best Practices Workshop, 2013).

Initially, some statistically significant differences were identified between CC transfer and non-transfer students to the CoE. Specifically, the one-year retention rates in the CoE, grade point averages after transfer, ACT mathematics scores, and high school GPAs were significantly lower for CC transfer students than non-transfer students. Furthermore, CC transfer students who left the CoE also left the university at higher rates than non-transfer students. Somewhat surprisingly there were significantly lower percentages of females enrolled in engineering at the CC and the female students who were enrolled had significantly lower retention rates than non-transfer females.

A holistic, sustainable approach was designed to promote the study of engineering comprehensively through the creation of EGR 100, the orientation course offered at CCs that has seen increased participation rates of women and minorities. At DMACC the participation rate for women has increased from 7% to 17%, and the participation rate of URMs has increased from 5% to 16%.

To engage transfer students while still at the CC and to support them throughout their studies and through the transfer process, the creation of E-APP increased the participation rates and statistically significantly increased the one-year retention rates of DMACC CC transfer students to the CoE. Among the best practices recommended by the successful E-APP are the presence of an academic advisor at the four-year institution who works directly with students at the two-year institution, peer mentors at the university, transfer articulation between the institutions, and increased connections between the CC and the university.

Important messaging has been developed inter-institutionally. Numerous transfer advising materials and communications for CC stakeholders have been developed and distributed as a result of this project. Since the inception of the project, DMACC and ISU's CoE have seen a notable increase in the number of pre-engineering students, the number of students enrolled in EGR 100, the number of students participating in the E-APP LC, the number of students transferring to the university, the number of transfer students participating in a LC at ISU, and an increase in first-year retention at ISU of students from DMACC as well as students from other Iowa CCs. These elements of the SEEC project ultimately have led to an increase in the number of students graduating with an engineering degree from ISU.

ACKNOWLEDGMENT

This material is based upon work supported by the National Science Foundation under Grant No. 0653236. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

We are grateful to the Des Moines Area Community College administration, faculty, staff, and students for their vital contributions to this partnership and for continuing to sustain and develop programs promoting engineering.

REFERENCES

American Association of Community Colleges. 2013. "Community college fast facts." Last Accessed March 31. http://www.aacc.nche.edu/AboutCC/Documents/FactSheet2013.pdf

Astin, A. 1993. What matters in college? (1st ed.). San Francisco, CA: Jossey-Bass Publishers.

Community College Survey of Student Engagement. 2007. "Overview of National 2007 CCSSE Cohort Survey Results". Accessed March 30. http://www.ccsse.org/.

Des Moines Area Community College Annual Report. 2015, accessed September 2016. https://www.dmacc.edu/annualreport/Pages/welcome.aspx

Hagedorn, L., H. Moon, S. Cypers, W. Maxwell, and J. Lester. 2006. "Transfer between community colleges and four-year colleges: The all-American game." *Community College Journal of Research and Practice, 30*(3):223–242.

Hagedorn, L., and A. Purnamasari. 2012. "A Realistic Look at STEM and the Role of Community Colleges." *Community College Review 40*(2):145–164.

Handel S., and R. Williams. 2012. "The promise of the transfer pathway, The Initiative on Transfer Policy and Practice", College Board.

Hastie, T., R. Tibshirani, and J. Friedman. 2001. The elements of statistical learning: Data mining, inference, and prediction. New York: Springer-Verlag, 2001.

Iowa State University Learning Communities. 2012. "Fifteen Year Success Rates." http://www.lc.iastate.edu/LC_15yr_success.html

Iowa State University STEM Student Enrollment and Engagement through Connections. 2013. http://www.eng.iastate.edu/seec/homepage.html

Iowa State University STEM Student Enrollment and Engagement through Connections. 2013. Best Practices Workshop. http://www.eng.iastate.edu/seec/practices/workshop.html, and https://www.youtube.com/watch?v=WZnJSEP-xjY&index=2&list=PLkFJXNkdkAEoDZr2K1Xkq0Li7EDnFE3o-

Jacobi, M. 1991. "Mentoring and undergraduate academic success: A literature review." *Review of Educational Research 61*(4):505–32.

Kaplan, E., and P. Meier. 1958. "Nonparametric estimation from incomplete observations." *Journal of American Statistical Association, 53*(282): 457–481.

Kisker, C. 2007. "Creating and sustaining community college--university transfer partnerships". *Community College Review 34*(4), 282–301.DOI: 10.1177/0091552107300333

Kline, R. 2011. *Principles and practice of structural equation modeling* (3rd ed.). New York, NY: Guilford Press.

Korte, R., and K. Smith. 2007. "Portraying the academic experiences of students in engineering: Students' perceptions of their educational experiences and career aspirations in engineering." In *Proceedings of the American Society for Engineering Education Annual Conference and Exposition.* Honolulu, Hawaii.

Laanan, F. 2007. "Studying transfer students: Part II: Dimensions of transfer students' adjustment." *Community College Journal of Research and Practice, 31*(1): 37–59.

Laugerman, M., and S. Mickelson. 2011. "Characteristics of Community College Transfer Students that Successfully Matriculate and Graduate in Engineering." American Society of Engineering Education Annual Meeting, Vancouver, British Columbia, Canada, June 2011.

Laugerman, M., and M. Shelley. 2013. "A structural equation model correlating success in engineering with academic variables for community college transfer students." American Society of Engineering Education Annual Meeting, Atlanta, Georgia, June 2013.

Laugerman, M., M. Shelley, S. Mickelson, and D. Rover. 2013. "The Engineering Admissions Partnership Program: A navigation strategy for community college students seeking a pathway into engineering" *International Journal of Engineering Education 29*(5): 1260–1269.

Laugerman, M., D. Rover, S. Mickelson, and M. Shelley. 2015. "Determining Graduation Rates in Engineering for Community College Transfer Students Using Data Mining." *International Journal of Engineering Education 31*(6A), 1–10.

Laugerman, M., M. Shelley, D. Rover, and S. Mickelson. 2015. "Estimating Survival Rates in Engineering for Community College Transfer Students Using Grades in Calculus and Physics." *International Journal of Education in Mathematics, Science and Technology, 3*(4), 313–321.

Levin, J., and J. Wyckoff. 1990. "Identification of student characteristics that predict persistence and success in an engineering college at the end of the sophomore year: Informing the practice of academic advising." Division of Undergraduate Studies Report No. 1990. 1, Pennsylvania State University.

McGready, J. 2006. "When time is of interest: The case for survival analysis." Baltimore, MD: The Johns Hopkins University. Retrieved from http://distance.jhsph.edu/breezeContent/537/6.pdf.

Mullin, C. M. 2012 "Transfer: An indispensable part of the community college mission." (Policy Brief 2012-03PBL). Washington, DC: American Association of Community Colleges

Mullin, C. M. 2012b. "Why access matters: The community college student body." (Policy Brief 2012-01PBL). Washington, DC: American Association of Community Colleges.

Myers, K., S. Silliman, N. Gedde, and M. Ohland. 2010. "Comparison of Engineering Students' Reflections on Their First-Year Experiences." *Journal of Engineering Education 99*(2):169–178.

National Academy of Engineering. 2013. "Messaging for Engineering: From Research to Action." National Academies Press, Washington, DC. ISBN 978-0-309-26180-7

National Academy of Engineering. 2008. "*Changing the Conversation*: Messages for Improving Public Understanding of Engineering." The National Academies Press, Washington, DC. ISBN 978-0-309-11934-4

National Academy of Engineering. 2004. "The Engineer of 2020: Visions of Engineering in the New Century." The National Academies Press Washington, DC:

National Research Council. 2005. "Enhancing the community college pathway to engineering careers." The National Academies Press, Washington, DC:

National Student Clearinghouse Research Center. 2012. Accessed November 4. *www.studentclearinghouse.org/snapshot.*

President's Council of Advisors on Science and Technology (PCAST). 2012. "Report to the President. Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics." Washington, DC.

Ragins, B., and J. Cotton. 1999. "Mentor functions and outcomes: A comparison of men and women in formal and informal mentoring relationships." *Journal of Applied Psychology 84*(4):529–50.

Sullivan, M., C. de Cohen, M. Barna, M. Orr, R. Long, and M. Ohland. 2012. "Understanding engineering transfer students: Demographic characteristics and educational outcomes." In *Frontiers in Education Conference (FIE), 2012* (pp. 1–6). IEEE.

Suresh, R. 2006. "The relationship between barrier courses and persistence in engineering." *Journal of College Student Retention, 8*(2):215–239.

Taylor, K., W. Moore, J. MacGregor, and J. Lindblad. 2003. "Learning community research and assessment: What we know now." (National Learning Communities Monograph Series). Olympia, WA: The Evergreen State College, Washington Center for Improving the Quality of undergraduate Education.

Tinto, V. 1997. "Classrooms as communities: Exploring the educational character of student persistence." *Journal of Higher Education, 68*(6):599–623.

Tinto, V. 2006. "Research and practice of student retention: What's next?" *Journal of College Student Retention 8*(1):1–19.

Tsapogas, J. 2004. "The Role of community colleges in the education of recent science and engineering graduates." (NSF 04-315). Arlington, VA: National Science Foundation.

Veenstra C., E. Dey, and G. Herrin. 2009. "A model for freshman engineering retention." *Advances in Engineering Education, 1*(3):1–33.

Whalen, D., and M. Shelley. 2010. "Academic success for STEM and non-STEM majors." *Journal of STEM Education, 11*(1 & 2): 45–60.

Zhao, C-M., and G. Kuh. 2004. "Adding value: Learning communities and student engagement." *Research in Higher Education, 45*(2):115–138.

Zhang, G., T. Anderson, M. Ohland, R. Carter, and B. Thorndyke. 2004. "Identifying factors influencing engineering student graduation and retention: A longitudinal and cross institutional study." *Journal of Engineering Education, 93*(4):313–320.

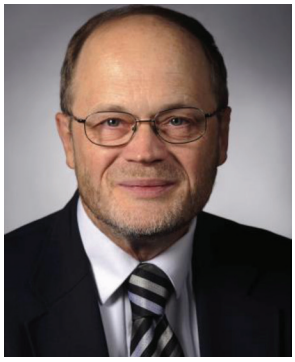
Zhang, G., Y. Min, M. Ohland, and T. Anderson. 2006. "The role of academic performance in engineering attrition." In Proceedings of the American Society for Engineering Education Conference and Exposition, Chicago, IL.

AUTHORS

Marcia Laugerman, PhD, PE, is an Assistant Professor of Practice in Statistics at Drake University in the college of business and public administration. She teaches undergraduate business statistics, and graduate MBA hybrid and online courses in business analytics. She is currently designing an online statistical modeling course for the graduate Master of Data Analytics Leadership major. She holds a BS and MS degree in Industrial Engineering, and PhD in Industrial Technology. She is a licensed professional Engineer in the state of Iowa. She has worked on numerous national research grants, and has numerous research publications in Science, Technology, Engineering, and Mathematics (STEM).

Diane Rover, PhD, is a University Professor of Electrical and Computer Engineering at Iowa State University. She currently serves as the alliance director for the NSF-funded IINSPIRE LSAMP Program, co-leads projects in the department funded by NSF RED and S-STEM programs, and is a co-PI of the new NSF Center for Advancing Research Impact in Society led by the University of Missouri. Her teaching and research has focused on embedded computer systems, reconfigurable hardware, parallel and distributed systems, visualization, performance monitoring and evaluation, and engineering education. She has held officer positions in the ASEE ECE Division, served as an associate editor for the ASEE Journal of Engineering Education, and served on the IEEE Committee on Engineering Accreditation Activities, the IEEE Education Society Board of Governors, the ABET EAC (2009-2014), and EAC Executive Committee (2015-2018). Dr. Rover is a Fellow of the IEEE and of ASEE.

Steve Mickelson, PhD, is a professor in the Department of Agricultural and Biosystems Engineering (ABE) at Iowa State University (ISU). Since 2011 he has served as the Chair for ABE and is the inaugural recipient of the Charles R. and Jane F. Olsen Professorship in Engineering. During his tenure as Department Chair, the department has risen to the top ranking (1st Place) among ABE departments in the US according to US News. Dr. Mickelson's teaching expertise is in engineering computer graphic, engineering design, and engineering workplace competency development and his research focus areas includes evaluation of agricultural best practices for reducing surface water contamination and the scholarship of teaching and learning.



Mack Shelley, PhD, is a faculty member in the Departments of Political Science and Statistics at Iowa State University, where he holds the title of University Professor of Political Science, Statistics, and School of Education. He currently serves as Chair of the Department of Political Science. His research, teaching, and grants activity address issues of public policy focused on education and other aspects of societal issues.

APPENDIX

The following websites have been created and sustained (as of September, 2016). Iowa State University:

- The SEEC project website http://www.eng.iastate.edu/seec/
- College of Engineering transfer website: http://www.engineering.iastate.edu/transfer/ Which includes a new pages with resources for Iowa community college students:
    - Engineering Admissions Partnership Program http://www.engineering.iastate.edu/transfer/engineering-app/
    - Community college (CC) transfer plans including courses by CC and credits http://www.engineering.iastate.edu/transfer/community-college-transfer-guide/
- SEEC project has proposed a case study for the NAE's online CTC community, based on our STEP-funded work http://www.engineeringmessages.org/TakeAction/TheCTCBlog/26051.aspx
- The following online examples of products were referenced:
    - Brochure developed for Iowa State University College of Engineering: http://www.eng.iastate.edu/seec/COERecruitmentBrochure.pdf
    - Iowa State College of Engineering Twitter page, an example of online content and social media using design/messaging elements of the original brochure: https://twitter.com/ISU_CoE
- Engineering transfer learning communities are now available. Several were launched in relation to this STEP project. The list is maintained here: http://www.lc.iastate.edu/transferlc_index.html

Des Moines Area Community College (DMACC). (Note: to view these sites select ok without entering a username or password:

- DMACC's Pre-engineering website http://go.dmacc.edu/programs/pdp/engineering/Pages/welcome.aspx
- DMACC's Pre-engineering Advising Guide https://go.dmacc.edu/programs/pdp/engineering/Pages/preengineering-ames_boone.aspx
- DMACC's online Pre-Engineering Resource Kit https://go.dmacc.edu/programs/pdp/engineering/Pages/engineering-kit.aspx
- DMACC Engineering brochure: http://go.dmacc.edu/programs/pdp/engineering/Documents/dmaccpreengineerigbrochure.pdf
- DMACC pre-engineering advising guide. A new resource was developed by the college's transfer coordinator as part of a master's degree project, the Iowa Community College Transfer Advising Manual http://www.engineering.iastate.edu/transfer/files/2013/06/CC-Engineering-Transfer-Advising-Manual-SPR13.pdf