Engaging Early Engineering Students (EEES): A Fourth Year Report from an NSF STEP Project

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1. Introduction

This report is a not a traditional conference paper. In this report we describe the progress of an NSF-funded Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) project. The report is based on our STEP Third Year Review report. The broad process timeline for a STEP project typically includes a lifetime of five years, with a milestone during the third year of operation that is an NSF checkpoint. This Third Year Review is centrally important to every STEP project that is a standard Type 1 project; the data conveyed to NSF determines whether or not the fourth and fifth year of the project will be funded by NSF.

The complete title of our STEP project is "EEES: Engaging Early Engineering Students to Expand Numbers of Degree Recipients". In this report we will refer to our project as simply ***EEES***.

We have two goals in presenting our Third Year Review report as an ASEE conference paper. First, we inform the community of progress of our STEP project with enough detail for members of the community to determine if facets of our approach may be applicable in their environments. This of course is the standard goal of many technical communications in engineering education.

Our second goal is more specific. By providing an exemplar of material that is part of a written record of a Third Year Review of a STEP project, we hope to make the STEP program more transparent to the entire community. While STEP projects are highly variable in both goals and program implementation, all STEP (Type 1) projects have goals of increasing numbers of STEM graduates. Thus, from a global perspective all STEP projects have the responsibility to develop data resources and assessment methods to determine if that top level goal is being met. Hence, a high level commonality can be expected across Third Year Review reports within the STEP program.

The bulk of this report is organized as follows:

- **Section 2** is a top level description of the relevant elements of the academic environment in which our STEP project is implemented, and a top level description of the four programs that together make up our project.

- **Section 3** is a description of the ***EEES*** peer-led tutoring components: *SI* (at Lansing Community College) and *PAL* (in the College of Engineering, Michigan State University).
- **Section 4** is a description of the ***EEES*** component connecting engineering faculty to early engineering students: the Connector Faculty (CF) component.
- **Section 5** is a description of the diagnostic component of our Diagnostic/Early Intervention program of ***EEES***.
- **Section 6** is a discussion and interim conclusion.

2. Global View of Environment of *EEES* and Introductory Description of *EEES* Components

EEES is a collaborative STEP project between Michigan State University (MSU) and Lansing Community College (LCC). The top level goal of ***EEES*** is to increase the matriculation-to-graduation retention rate of engineering undergraduate students by ten percentage points over the course of our project. Preliminary results indicate that we have progressed more than halfway to that goal based on data for the first cohort of students served.

MSU admits students first to the university, without any considerations regarding intended major. A student is admitted to the College of Engineering in one of our ten undergraduate degree programs after completing six key courses, provided a threshold GPA is attained. At the margin, students must be admitted to a degree granting college by the time they reach junior standing (56 credits). Typically, most successful engineering students will be admitted to the College of Engineering by the point they complete their fifth semester. Once students are admitted to the

Retention Rate for Domestic Engineering Intenders: Counting from Matriculation

	end term 2	end term 3	end term 4	end term 5
2006	77.6%	65.0%	56.6%	45.2%
2007	81.7%	69.8%	57.3%	47.4%
2008	79.2%	69.6%	60.3%	53.5%

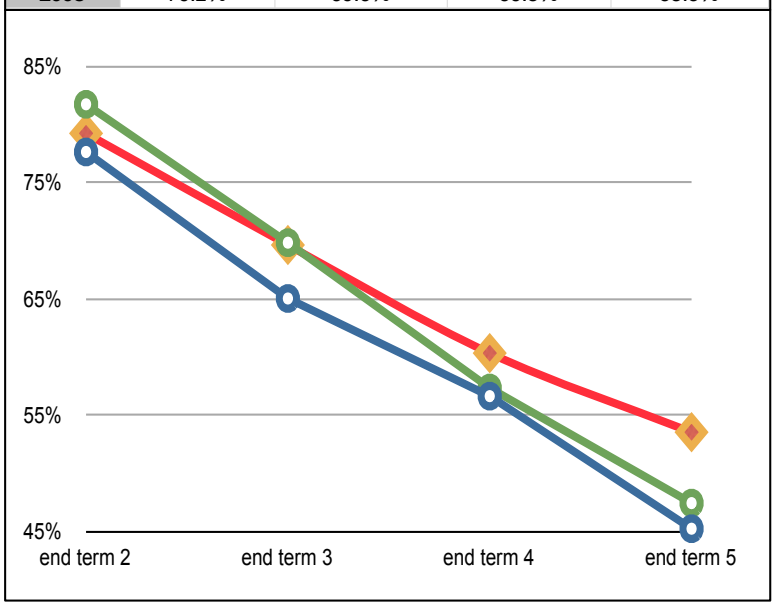

Figure 1: Term-to-Term Retention Rates for Domestic Engineering Intenders - Counting from Matriculation

College in their chosen major, graduation in the program is achieved by approximately 85% of students. From that point forward, attrition is largely linked to students' personal reasons and are not amenable to programmatic intervention. Thus an intermediate measure of our overarching goal is **retention five semesters after matriculation**. Figure 1 above shows an increase in matriculation-through-term-5 retention rate of **6.1 percentage points** between the last cohort before our STEP project began (2007) and the first cohort after our STEP project began (2008).

We have designed ***EEES*** to have four components, each of which targets a well defined student impact. Three of the four components are voluntary for students, while the fourth is a defined part of our second semester course for first year students. Below we briefly describe the four components of ***EEES***.

Project Component for Peer-assisted Learning (PAL): The PAL program is aimed at addressing academic difficulties of first year engineering students. The PAL program is strongly collaborative between LCC and MSU; and indeed in this collaboration, MSU is the junior partner. LCC has had a strong and effective program in "Supplemental Instruction" (SI) for close to two decades. SI is a peer-led learning/mentoring program; the LCC variant of SI is largely patterned after the "Kansas City model." With LCC's long history in SI, they led the early effort in ***EEES*** to develop the PAL program. That included training and instruction for both PAL team members and training of the initial group of peer leaders. It is important to remember that this component of ***EEES*** is different at the two institutions because of the history differences between the two institutions.

Project Component for Connecting Early Engineering Students to Engineering Faculty - Connector Faculty (CF): CF is targeted to better connect first year MSU engineering students to engineering faculty and to the College of Engineering. The CF component of ***EEES*** is the only component that does not engage project partners at LCC currently. The literature indicates that a significant percentage of academically high achieving first year students voluntarily choose to leave engineering. Root causes prominently include the sense of students that they are adrift because they lack anchors to the faculty and to the college. Success in CF is measured by the objective outcome that students who participate in CF are more likely to be admitted to an undergraduate engineering major than those who do not participate in CF.

Project Component for Diagnostics-driven Early Intervention (Dx/Early): The Dx/Early component of ***EEES*** has three facets: (i) developing and stabilizing an instrument that can be used to predict early in a term that a student will attain a lower than acceptable course grade, (ii)

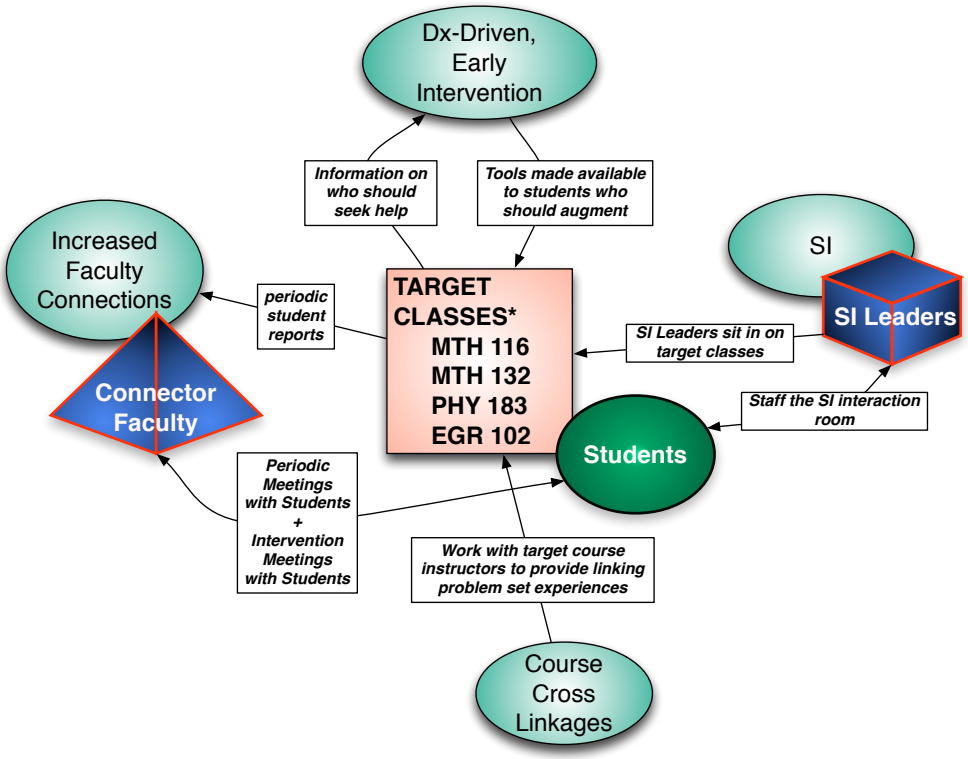

Figure 2: The four working components of the ***EEES*** Project

a means to identify specific areas of student difficulty, and (iii) implementing a remediation program that will help students to address their areas of difficulty.

Project Component for Course Cross Linkages: In this curricular component, material from predecessor math and subsequent physics will be used to develop problems for EGR 102, a required engineering problem solving course, which includes computing and numerical methods components.

The four ***EEES*** components and their interrelations are show graphically in Figure 2 above.

3. Peer-led Tutoring Component

There are many programs across the country that address tutoring needs of students. One is the widely implemented "Supplemental Instruction" model, which is based on peer-led class review sessions of students, especially those in historically challenging courses. The supplemental instructional (SI) model adopted at LCC over a decade ago is derived from the Kansas City model of voluntary participation in out-of-class sessions and hence the name "supplemental."

With strong assistance from the more experienced hands at LCC, the model adopted at MSU largely followed the voluntary Kansas City model initially.

We have focused substantial effort to establish PAL at MSU as a tutoring opportunity in traditionally challenging, early engineering courses. Simultaneously we have extended SI at LCC to cover the courses at LCC mirroring the same pre-engineering courses.[1]

From the outset we have noted differences in PAL/SI results in the two environments. From the outset at MSU we have experienced low rates of participation for PAL while at LCC participation has been substantially higher. Very substantial discussion based on the data of participation rates have driven the MSU's PAL program to mutate towards a revised model we have of a common setting for all PAL courses in recognized and stable locations on campus. In keeping with other programs at MSU, we are calling this the "neighborhood approach" to the PAL component. The table in Appendix B shows the chronology of PAL developments at MSU and how the results noted for one semester leads to component changes that follow.

Until Fall 2010, we did not have results for objective learning outcomes from PAL/SI. In Fall 2010, we reached a stage of stability with the PAL program that supported studying the learning outcomes for PAL at MSU, and concurrently studying the learning outcomes for SI at LCC.

Preliminary reports for two studies follow:

- The effect of SI on learning outcomes in pre-engineering courses at LCC.
- The effect of PAL on learning outcomes in pre-engineering courses at MSU.

The most concise way of reporting the results is:

- At LCC, SI is well attended and appears to have significantly positive effect on learning outcomes in most pre-engineering courses.
- At MSU, PAL is poorly attended and appears to have no significant effect on learning outcomes in most pre-engineering courses.

3.1. Academic outcomes for students participating at MSU in PAL for Fall, 2010

Based on the SI models, PAL targets traditionally challenging courses that are barriers to student admission to the College of Engineering, so we are interested in the impact of PAL on student

[1] Pre-engineering courses were not covered by LCC SI prior to ***EEES***.

outcomes in these courses. While there is extensive literature on the outcomes of students who participate in SI programs, most of these reports compare the overall outcomes for students who participated vs. those who did not, without controlling for other variables that might impact outcomes. We wanted to understand what, if any, differential impact there was for PAL, when controlling for other variables such as type of course, academic ability and demographic variables.

During fall, 2010, PAL at MSU was offered to students in Math 116 (College Algebra and Trigonometry), Math 132 (Calculus 1) and Physics 183 (Physics 1). The proportion of eligible students attending PAL was low (6.9% in 116; 8.3% in 132 and 14.3% in PHY 183.) Because of the small proportion of students attending PAL sessions and the fact that the distribution of the number of sessions any individual attended is not normally distributed, we treated PAL attendance as a binary variable: students attending one or more sessions were grouped as attending PAL. Due to the small numbers of students in non-white ethnicity categories, ethnicity data were recoded into binary variables for Black, Hispanic, Native American (includes Alaskan) and White categories. Depending on the course, we used Math ACT scores, initial Math gateway exam scores, and/or overall GPA as measures of student academic abilities in these courses.

3.1.1. Math 132 Analysis

Of students enrolled in Math 132, 8.3% of students (n=92) attended one or more PAL sessions. The students attending PAL were not significantly different from students who did not attend on any of the univariate measures (initial gateway exam scores, ACT Math score). However, final course grades of students who attended PAL in 132 were lower than students who did not attend PAL (non-PAL, mean = 2.52, std. dev. = 1.23; PAL, mean = 2.15, std. dev. = 1.11; $p < .006$).

To determine if there are interactions among variables that impact outcomes, we performed a regression analysis to predict Math 132 final grade. Because many of the students are first term freshmen, we could not use GPA as a predictor variable. However, the first Math gateway exam was given early in the semester and taken by all students in the course is a stronger predictor of the final course grade (r=.38) than ACT Math (r= .32). We used Math ACT, first Math gateway score, PAL attendance, gender, citizenship, Black, and White ethnicity categories as independent variables. The resulting model accounts for 20.2% of the variance (R2 = .202). The Math gateway score (beta = .313) and Math ACT (beta = .207) where significant. There were gender differences (beta = .120, $p< .001$), meaning that, when controlling for all other variables, women on average earned a .14 higher grade in 132. PAL attendance (beta = -.088, $p < .005$) also had impact on students' grades. However, the negative beta means that, when controlling for other variables, on average, students who attended PAL for 132 earned a .1 lower grade. It is not clear

why this would be, but since the regression accounts for only 20% of the variance, there are other factors which we did not measure that may account for this outcome.

3.1.2. PHY 183 Analysis

Overall grades in PHY 183 are much higher with less dispersion (mean = 3.23, std. dev. = .81) than either Math 116 or 132. Of students enrolled in Physics 183, 14.3% of students (n=66) attended one or more PAL sessions. Students who attended PAL sessions had lower ACT Math scores (mean = 26.5) than non-PAL students (mean = 27.7; $p < .02$) but there were no differences between PAL and non-PAL students on incoming GPA or on final grade in 183.

To determine if there are interactions among variables that impact outcomes, we performed a regression analysis to predict Physics 183 final grade. Because many students in Physics 183 are sophomores, we were able to obtain overall GPA for most (336 of 396) of the students. We used GPA, Math ACT, PAL attendance, gender, citizenship, Black, and White ethnicity categories as independent variables. The resulting model accounts for 30.5% of the variance ($R^2 = .305$). GPA (beta= .415) and Math ACT (beta = .209) where significant. There were gender differences (beta = -.103, $p < .05$), meaning that, when controlling for all other variables, women on average earned a .08 lower grade in 183. Non-citizens received slightly higher grades than U.S. citizens (beta = .123, $p < .02$). When controlling for other variables, there were no significant differences based on students' ethnicity. PAL attendance (beta = .114, $p < .02$) had a positive impact on students' grades. When controlling for other variables, on average, students who attended PAL for 183 earned a .09 higher grade.

3.1.3. Discussion

Because PAL is a voluntary program that has been evolving, students may still not be aware of what the program offers. Hence, PAL attendance has been low for all courses, although it is higher in physics than in either math course. After controlling for academic and demographic variables, it appears that the impact of PAL is very modest, ranging from no impact in 116, a slight negative impact in 132 and a slight positive impact in 183. Given that the regression models account for only 20-30% of the variance, there are many other factors that are not being measured that may impact students' outcomes. However, the overall differences in student outcomes are slight. It is possible that higher levels of student participation may produce better results, since the small numbers result in wide variability in the outcomes.

Table 1: Students attending 2 or more SI sessions by course.

Course		Number of Students	Percent	Mean # sessions
CPSC131	0-1 Session	49	60.5	
MATLAB	2+ Sessions	32	39.5	6.5
	Total	81	100.0	
MATH121	0-1 Session	213	77.7	
Algebra	2+ Sessions	61	22.3	7.7
	Total	274	100.0	
MATH122	0-1 Session	148	87.6	
Trig	2+ Sessions	21	12.4	6.0
	Total	169	100.0	
MATH151	0-1 Session	165	64.5	
Calc I	2+ Sessions	91	35.5	7.3
	Total	256	100.0	
MATH152	0-1 Session	77	56.6	
Calc II	2+ Sessions	59	43.4	8.3
	Total	136	100.0	
MATH253	0-1 Session	61	83.6	
Calc III	2+ Sessions	12	16.4	8.3
	Total	73	100.0	
PHYS251	0-1 Session	40	47.1	
Physics I	2+ Sessions	45	52.9	14.4
	Total	85	100.0	
PHYS252	0-1 Session	42	51.9	
Physics II	2+ Sessions	39	48.1	10.4
	Total	81	100.0	

3.2. LCC SI Analysis for courses supported by *EEES*

SI has been implemented at LCC in a large number of courses for 22 years and LCC has institutionalized the program; most students are aware of it. Starting in Fall semester, 2008, ***EEES*** funds were used to add SI support for courses taken by LCC students planning to transfer to the MSU engineering program or to other four-year engineering institution. These courses had not previously had SI support. This analysis shows the impact of SI on student academic outcomes by each course since Fall, 2008.

Due to the institutionalization of SI, participation rates at LCC are high, even though the program is voluntary. Table 1 above shows the courses, the numbers/percentages of students enrolled in each course who attended 2 or more SI sessions, and the average number of sessions.

Table 2: Final grade distribution by course.

	Final Grade Distributions by Course										
	0.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0	I	W	X
CPSC131		1.2%	1.2%	11.1%	9.9%	23.5%	19.8%	11.1%		21.0%	1.2%
MATH121	8.4%	1.8%	5.5%	10.2%	11.7%	16.8%	12.8%	14.6%	.4%	17.9%	
MATH122	7.7%	6.5%	4.1%	10.1%	9.5%	11.2%	17.8%	16.0%	.6%	16.6%	
MATH151	14.1%	2.7%	5.5%	14.1%	11.3%	10.9%	9.0%	12.5%		18.4%	1.6%
MATH152	15.4%	3.7%	12.5%	11.8%	12.5%	13.2%	8.8%	5.9%	.7%	15.4%	
MATH253	13.7%	5.5%	1.4%	9.6%	15.1%	11.0%	12.3%	19.2%		11.0%	1.4%
PHYS251			5.9%	7.1%	11.8%	21.2%	14.1%	10.6%	1.2%	27.1%	1.2%
PHYS252	1.2%	3.7%	1.2%	3.7%	11.1%	21.0%	22.2%	14.8%	1.2%	19.8%	
Total	9.0%	3.1%	5.3%	10.6%	11.4%	15.0%	13.4%	13.1%	.4%	18.1%	.6%

While participation in SI varies widely by course, students who do participate tend to attend a fair number of times, suggesting that they find these sessions worthwhile.

3.2.1. Grade Distributions

LCC allows students to withdraw from a course for any reason through week 8 of the semester. After week 8 until the end of the semester, a student may also withdraw from a course up to the end of if s/he has a grade of at least 1.0. Table 2 above shows the distributions of grades for each course. Note that the average DFW (grade < 2.0 or withdrawal) rate ranges from 24% to 47% across the courses.

Because SI targets traditionally challenging courses (those with high DFW rates) rather than at-risk students, outcomes are often reported comparing pass rates (2.0 or higher) for students who participate in SI with those who do not participate. Table 3 to the right shows the percentages of students who received 2.0 or higher in each course for students who attended 0 or 1 sessions compared with students who attended 2 or more sessions.

Table 3: Pass rates (grade 2.0 or better) for students attending SI by course

	0 or 1 SI Session	2 or more SI Sessions
CPSC131	73%	81%
MATH121	63%	79%
MATH122	66%	57%
MATH151	48%	79%
MATH152	38%	72%
MATH253	62%	100%
PHYS251	51%	80%
PHYS252	63%	85%

There is much debate, though little reported research, on the impact of voluntary SI programs on student outcomes. Since participation is voluntary, it is not clear if better student outcomes

that are frequently reported for SI (such as those in Table 3) are due to students who are more academically capable attending SI more frequently.

To control for academic ability when analyzing the impact of SI on student outcomes, we performed regression analyses for each course, using the math placement score, grade in the prerequisite course, overall GPA at the start of the semester, and gender to control for student prior academic and to determine if there are different outcomes by gender. The dependent variable was the grade in the course treated as a binary variable to account for the large proportions of withdrawals. We compared DWF with grades >=2.0. We used a binary variable for SI participation: 0 or 1 sessions compared with 2 or more sessions because the participation rates are not normally distributed. We used SPSS V 19 for all analysis and performed 1000 bootstrap iterations to estimate confidence intervals for all regression coefficients, using a 95% confidence interval for significance.

Just as SI participation and final grades vary by course, so do the impacts. The results are shown in Table 4 to the right.

Table 4: Summary of regression analysis by course for impact of SI on course outcomes, controlling for student academic ability

Course	Overall model R^2	Beta for SI	Average Increase in Number of 2.0+ grades for SI Participants	Average increase in Course Grade for SI Participants not Withdrawing
CPSC131	.055[1]	-.019[1]	N/A	N/A
MATH121	.239[2]	.193[3]	9%	.16
MATH122	.159[2]	-.067[1]	N/A	N/A
MATH151	.338[2]	.348[2]	17%	.24
MATH152	.431[2]	.219[4]	11%	.31
MATH253	.524[2]	.104[1]	N/A	N/A
PHYS251	.422[2]	.312[3]	15%	.08
PHYS252	.316[2]	.151[1]	N/A	N/A

1. Not Significant
2. Significant p < .000
3. Significant p < .01
4. Significant p < .05

The F-tests for the regression equations were significant for each course except CPSC131, where none of the independent variables produced a significant model. All other regressions were significant and account for between 16% and 52% of the variance in course grade (overall model R^2), depending on the course. The models for the core courses (calculus and physics) all had larger R^2 values than the other courses, likely due to the fact that students in those courses are further along in their programs and have more credits so their GPA is a better predictor of performance.

The Beta (standardized beta coefficient) for each variable shows the relative contribution of that variable when holding all other variables constant. For Math 121, 151, 152 and Physics 251, the Beta for SI was significant ($p < .05$), meaning that when controlling for academic ability, students who participate in SI perform better in these courses than students who do not participate in SI. The Beta coefficients can be used to calculate the average increases in student outcomes as a result of SI. The right two columns in Table 4 show this calculation two ways. First, the average increase in the number of students who receive a grade of 2.0+ vs. DFW students by course. Second, for students who received any grade (0 – 4.0) in the course, the average increase in the course grade for students who participated in SI compared with students who did not participate.

We included gender in each regression. The only course for which there was a difference by gender was Math 121, where women (who constituted 48% of the class), on average, earned a grade .22 lower than men. In all other courses, gender was not significant.

At LCC, 360 students have availed themselves of SI opportunities in the core engineering courses as a result of ***EEES***. While not every course shows statistically significant outcomes for SI, the crucial core courses that are major barriers for admission four year engineering programs show significant gains for students who participate in SI.

3.3. Discussion of PAL Component

There is an open research issue that has developed from our ***EEES*** project to date in SI/PAL that has national implications. There has been a developing sense that voluntary programs, and in particular voluntary tutoring programs, and with still more specificity, voluntary peer-led tutoring programs are ineffective in producing positive effects on objective learning outcomes. However, reports in the literature that substantiate this viewpoint are difficult to locate.

Our experience in the ***EEES*** project, and the SI/PAL component indicates that in the LCC environment voluntary peer-tutoring appears to be effective. But at the same time, our experience in the MSU environment is contrary to our LCC preliminary finding.

One possible explanation revolves around the long standing program at LCC versus the relatively new program at MSU. Another possibility is the set of quite substantial differences in the two institutions' cultures. The bottom line now is that we do not know why the LCC experience produces demonstrably positive results while the MSU experience has not yet produce similar positive results.

Our research agenda includes studying this issue in depth. If we can isolate the factors in the LCC environment that promote success in voluntary peer tutoring, we may be able to develop those same promotive factors in our MSU environment.

In the current economic environment that all higher education faces, developing a *successful* peer-led tutoring approach is important because of the relatively inexpensive scale-up that is possible in these programs.

4. Connector Faculty Component of our Project

In our STEP proposal, we highlighted the well-studied causes of student attrition from STEM majors. The goal of the Connector Faculty (CF) portion of ***EEES*** has been to counteract the attrition of qualified students by building effective student-faculty connections wherein students feel supported and welcome in engineering. Our focus is on building an effective program in the culture of an R1 university with relatively large numbers of first-year students. The program has been effectively and sustainably evolving and adjusting based on feedback obtained throughout the life of the project. This evolution and its data-driven basis are described in this summary and in the supporting evidence attached.

The kick-off of the CF component of ***EEES*** in Spring, 2009, involved assignment of trained volunteer faculty (Connector Faculty: CF) to groups of students from our introductory engineering course, EGR 100. CF were asked to meet with students at least once during the semester. Three large-group activities were organized. New faculty student assignments were made for the EGR 100 offering in Fall, 2009 and Spring 2010 with a similar format.

CF training was changed during this period to orient faculty to best practices (best topics to discuss) in meetings with students and to acclimatize faculty to realistic expectations for student responsiveness and willingness to meet. Many students were neither replying to invitations nor coming to CF meetings. In an effort to encourage initial student participation in CF, in Fall '09, the first CF-student meeting was focused around the students' completion of an EGR 100 homework assignment, thus making the first meeting between faculty and their students mandatory. Although faculty meetings with groups of students were encouraged, some faculty felt overwhelmed by a) the numbers of students approaching them with their homework questions and b) the time spent accommodating them.

During this time, college enrollment increased and recruiting of sufficient number of faculty to make the size of student groups manageable was an issue. Several models were used for faculty recruiting, including presentation at departmental faculty meetings, encouragement by the

college deans, personal interactions, and even recruitment of academic specialists to serve as CF. With the large enrollments in EGR 100, the student/faculty ratio still remained high. Faculty, none the less, remained enthusiastic about repeated semesters of service in this program.

In Fall, 2010, a new model of student engagement in the CF program was presented. EGR 100 students were allowed to 'opt in' to the CF program. About half of the students did so. While concern was expressed that students not really 'needing' the CF connection would choose to opt in, later results showed no such skewing. Faculty now had smaller, more manageable groups which were maintained throughout the entire 2010-11 academic year. I.e., new CF groups were not set up for the smaller, Spring '11 EGR 100 class. This, in a sense, also provided an opportunity for a "control group" for later analysis of results.

Fall 2010 also included a new social event for all EGR 100 students in which they were required to attend a "Freshmen Connect" program, one held for each engineering program early in the semester. This event featured orientation to the discipline, presentations by faculty, lab tours, and also allowed students to complete their EGR 100 assignment by roundtable discussions with individual faculty. The event also gave ALL EGR 100 students--even those who had not opted into the CF program--some 'connection' with departmental faculty. This is the current model for our CF program.

The following sections summarize the effectiveness of the CF program to date.

4.1. Summary of Evidence for the CF Component of *EEES*

There is evidence that the Connector Faculty (CF) program is having a positive effect on students.

- Students who participated in the first version of CF (Spring 2009) were admitted to the College of Engineering (COE) at a higher rate than those who did not participate.
- Surveys conducted in Fall 2009 and 2010 showed that students who participated in CF expressed more positive attitudes about the CF program and the likelihood of being accepted into the COE at the end of the semester than they had at the beginning of the semester.
- Student admission rate and attitude change were both positively correlated with frequency of interaction with faculty in the CF program: the more face-to-face meetings, the higher admission rate and greater attitude change.

Faculty participation is stabilizing and expectations remain positive.

- About half the faculty who responded to a recent (Spring, 2011) survey have had some participation in CF, and the majority of those intend to stay with the program.
- An additional 37% of faculty respondents are considering participation in the future. The proportion of those who say they might participate is slightly higher among those who have not as yet been part of the program.
- Participating faculty and those who intend to participate are predominantly tenured faculty. Lower ranked faculty express willingness to participate, but frequently mention that they are already in frequent contact with students.

The program is reaching the intended target population: potential 'leavers', i.e. students who are academically qualified by the junior year but choose another major.

- ACT scores were significantly higher for CF participants who were admitted to the COE vs. all admitted students.
- Incoming ACT scores were slightly higher for participants in CF than the group as a whole.

4.2. Major Findings

4.2.1. Admission Data

In the Fall 2010, the Office for Survey Research [OSR] surveyed students who had declared themselves intenders for admission to the COE in the academic year 2008-2009. These students were the first to have any exposure to the CF program in its initial form, and they are, to this point, the only students who could have gained admission to the college.

There was statistically significant evidence that those students who had been involved with CF were more likely to have been admitted. The greater their involvement, the higher the percentage of admissions.

- 65% of the students who participated at all in CF were admitted to the COE, compared to 57% of those who did not participate.
- 69% of the students who had at least one contact with a faculty member were admitted, vs. 50% of those who had no face-to-face contact but said they had participated in the CF program.

- The more frequently students met with faculty, the more likely they were to be admitted. Students who were admitted and had some face-to-face meetings average 3.6 times vs. 1.8 for those not admitted; 82% of the admitted students met more than once, vs. 40% of those not admitted.

We also asked, "Thinking back to the Fall of 2008, how committed were you to becoming an engineer?" There was no difference in level of commitment between those who participated in CF and those who did not, which speaks to the point that the students who participated were not more likely to be admitted than those who did not.

Finally, given the students targeted by the CF program--students whose grades are high enough to be admitted to the COE, but choose another major--we found support for the hypothesis that CF is properly targeted in that:

- Incoming scores on the ACT were slightly higher for participants in CF than the group as a whole

- ACT scores were significantly higher for CF participants who were admitted to the COE vs. all admitted students

4.2.2. Student-Faculty Interactions

A Spring, 2009 student survey investigated the correlation of students' evaluation of the program with topics discussed at meetings with CFs. Figure 3 below shows six topics the students seemed to use as a basis of judgment of the 'usefulness' of the program. The yellow (upper of pairs) bars indicate student perception of a helpful topic for those students who rated CF positively, while the red (lower) indicates a topic rating for student who gave CF a low rating (waste of time) (all at least to α=0.05). These results helped focus CF training topics.

4.2.3. Attitudinal Data

As previously reported, OSR surveyed the freshman intenders in the fall semesters of 2009 and 2010, and found ample evidence that the CF program promoted a more positive attitude in the students regarding the engineering program and the likelihood that they would be accepted into the COE.

Since the program has changed since the ***EEES*** effort began as described at the beginning of this report, the remainder of this report concentrates on the most recent (Fall 2010) student survey.

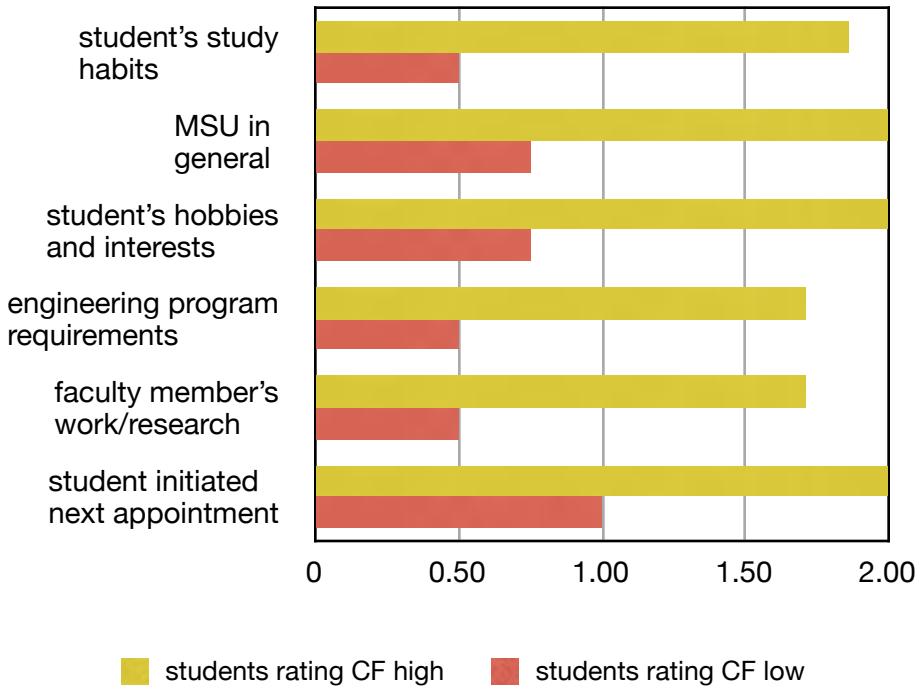

Figure 3: CF Topics as a Function of Student Rating of CF (Spr 2009 data)

- Question: "Thinking back to the beginning of the semester, what was your expectation of the usefulness of the Connector Faculty Program in achieving the goal of increasing student retention in the College of Engineering?"
  - 22% were convinced it would be useful, 65% were hopeful, 8% were doubtful and 5% thought CF would be of no use.
- Question: "Now that the semester is nearly over, how have your expectations about the Connector Faculty Program changed?"
  - 52% of the respondents answered that they were more positive, vs. 38% who said they were more negative. The remainder said their view was unchanged.
- Over the course of the semester, slightly more students who participated in CF (86% vs. 83%, $p>.05$, not statistically significant) said they felt sure they would be accepted into the program in their junior year.

4.2.4. Survey of Engineering Faculty: April 2011

An online survey was sent to 214 current and emeritus faculty members. Sixty-nine (32%) consented to fill out the survey. Table 5 to the right shows faculty rank and years experience of the respondents.

Table 5: Demographics for Faculty Rank and Experience and Average Years Teaching at MSU

Distribution of Faculty Rank and Experience					
	Full Professor	Associate Professor	Assistant Professor	Specialist	Other
number respondents	29	22	8	6	3
Average Yrs teaching EGR at MSU	22.3	14.4	4.0	15.5	32.0
Average Yrs teaching EGR at Other Institutions	5.9	3.3	0.4	3.2	4.0

- the respondents were tenured faculty
- 81% of the respondents had some familiarity with ***EEES***
  - Of the respondents who had some familiarity with the program, 94% thought it would have some positive effect on graduation and retention; 17% thought it would have a significant effect, and 77% thought it would have a slight positive effect.
  - In contrast, 90% of those who had no familiarity with the program voted for a small effect, and 10% said there would be no effect at all.

Respondents were asked to indicate whether or not they had been involved as Connector Faculty up to the present, and whether they intended to be involved in the future. Results are shown in Figure 4 to the right. Percentages refer to choice of future plan of those in each category of involvement. Thus 53% of those who have been involved to this point plan to continue, and 54% of those who have NOT been CF have no plan to join the effort in the future.

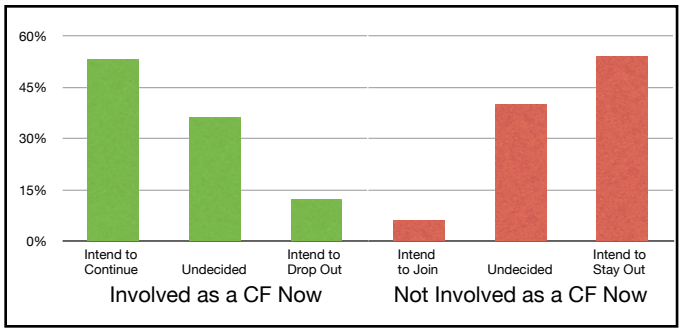

Figure 4: Planned Engagement in CF as Affected by Current Involvement

It is noteworthy that there is *no significant difference* in the average expected outcome of ***EEES*** as it might affect retention and graduation between the faculty who participated in the program and those who did not. There is a generally positive view of the expected outcome of the ***EEES***

program as to increasing retention. Overall, 86% of the respondents thought there would be a positive effect.

As shown in Table 6 to the right, those who have the fewest years of experience at MSU are the most optimistic, but no group is significantly below the group average of 86%.

Table 6: Number Years at MSU vs Positive Expectation for ***EEES***

MSU Experience Teaching	Expectation of Positive Results
1-5 yrs	100%
6-10 yrs	79%
11-15 yrs	91%
16-20 yrs	80%
>21 yrs	85%

An overview of the open-ended questions, which probed respondents to give their assessment of the ***EEES*** program overall impressions, positive and negative aspects of ***EEES***, change in perception of undergraduates, and reasons for the plan to be involved as CF in the future revealed that:

- A majority of the negative impressions had to do with a PERCEIVED low rate of responding, e.g. "only 3 of the 10 students assigned made and kept appointments".
- Faculty who had not been involved in CF and were not planning to do so frequently cited that they were already performing in that role; others cited lack of time or a belief that 'only the better students become involved.'
  - That belief indicates that they are unfamiliar with the goal of CF, which is to reach the better students who might opt for a different major even though they had performed well enough to be admitted to the COE.
- Several cited the very existence of ***EEES*** as a positive.
- In general, the faculty perception of first-year engineering students is unchanged.

Finally, we asked faculty to rate the importance of several different activities and to indicate the percentage of time they spent on each. Figure 5 below indicates the faculty perceived EFFORT vs. IMPORTANCE, as calculated by subtracting the relative importance of the activity from the time spent doing it, then dividing the remainder by the relative importance.

The respondents rated teaching at 15% relative importance, and spend 26% of their time doing it, yielding a +79% EFFORT vs. IMPORTANCE. Helping the students stay in engineering is rated at 17.6 percent importance, but is allotted only 14% of time, for a -20% effort relative to

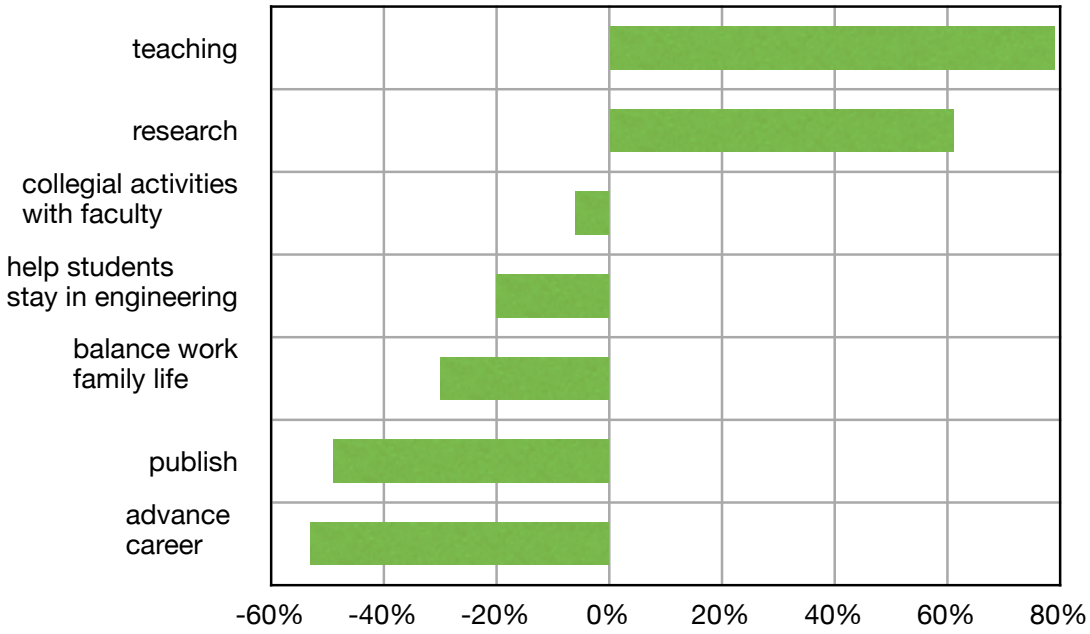

Figure 5: Faculty Perceived Effort minus Perceived Importance on Common Faculty Tasks

importance. This indicates that, while faculty rate helping students gain admission into an engineering major a very close third after research and publishing (all rounding to 18% relative importance), they spend much more time teaching courses and doing research (55%) than attempting to help students directly.

5. Dx/Early Component of our Project

A third component of ***EEES*** is our effort aimed at diagnosis of conceptual problems pre-engineering students encounter, and intervention steps to help them correct the conceptual problems. Current efforts in Dx/Early focus on mathematics. In particular this component targets Math 116 (College Algebra and Trigonometry), Math 132 (Calculus 1), and Math 133 (Calculus 2) at MSU, with mirroring in mathematics courses at LCC.

In the Mathematics Department, MSU, a "gateway exam" program has been in existence for a decade. This "gateway exam" is a program where in students in MTH 116, MTH 132, and MTH 133 are offered the opportunity to take a test comprised of items from a highly tuned bank of questions. The tuning is to align the problems to concepts that the students should be learning in the mathematics course they are enrolled in. In short, our goal is to raise the students' awareness to conceptual issues and in particular to learning deficits they need to attend to.

For example, in Calculus 1, there are two voluntary gateway examinations. One is at the start of the term, and is a gauge of how "prepared" the student is for doing well in Calculus 1. A second is given approximately half way through the term and is a gauge of the level of calculus understanding the student has gained over the semester.

As part of ***EEES***, an expanded database of questions was developed for the gateway examinations. In addition, there are indications of a developing trend that points to a higher utilization of the voluntary gateway program since the kick-off of ***EEES***. We believe that this might be due to the interaction of the gateway program with other ***EEES*** programs. Figure 6 and Figure 7 to the right show the results for fall semester for gateway exams given in Calculus 1 from 2004 through 2010.

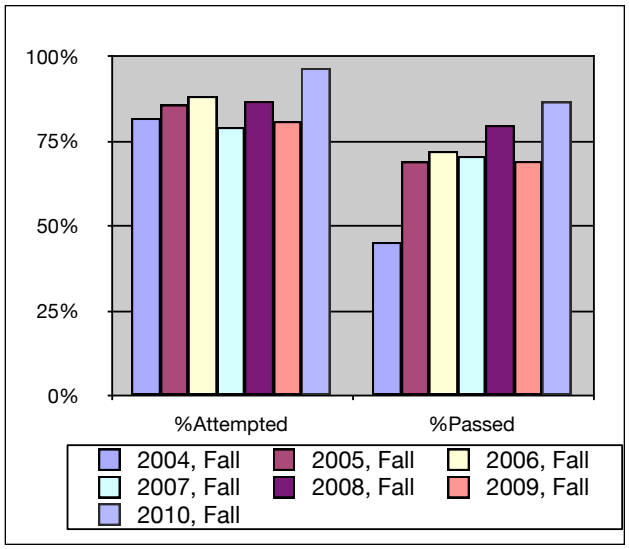

Figure 6: Gateway Exam 1 for Calc 1 - Fall Participation Rates and Passing Rates for 2004-2010

In Figure 6, the percentage of students who attempted gateway exam 1 in Calculus 1 and the percentage of students who passed gateway exam 1 are shown. The individual bars show the data for each fall semester from 2004 through 2010. Figure 7 shows corresponding results for gateway exam 2 in Calculus 1.

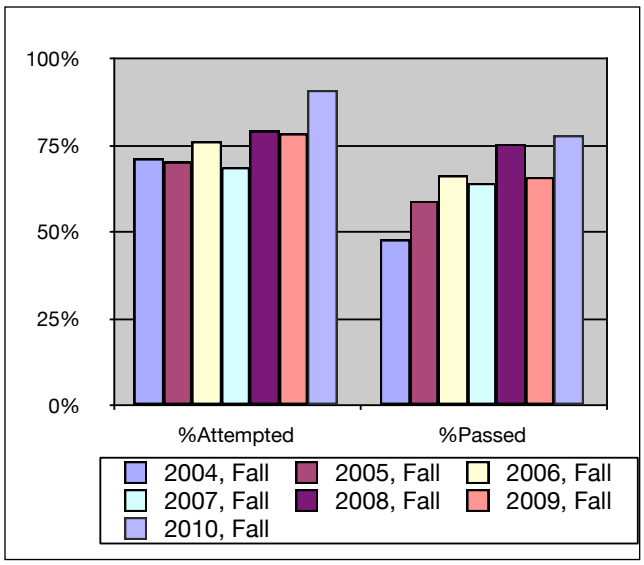

Figure 7: Gateway Exam 2 for Calc 1 - Fall Participation Rates and Passing Rates for 2004-2010

A preliminary conclusion based on the results shown in Figure 6 and Figure 7 indicate that the percentage of students voluntarily taking the gateway exams in Calculus 1 is increasing. The figures also, and more clearly, suggest that the percentage of students who are passing the gateways exams in Calculus 1 is increasing. Noting that 2008 is the first year of operation for the ***EEES*** program, there is preliminary evidence that ***EEES*** and the culture that ***EEES*** is developing

in our undergraduate population may be having an effect. Our research agenda includes further investigation on this issue.

The gateway examinations form the DIAGNOSTIC part of our Dx/Early component in mathematics. Our next steps with this component are to better isolate the results of the diagnostic gateway exam and to ultimately make it more transparent to the student which topics they should concentrate on. The last step we will develop is a set of targeted resources for students. These resources will provide students with the necessary tools to address their conceptual issues.

The cycle of diagnostics and intervention is not complete. But we believe the diagnostic basis of the gateway exam, and in particular the utility of the voluntary basis of the gateway for the Calculus 1 students is on a firm foundation.

6. Conclusion

The above report contains typical detail level for a large scale STEP project. While all STEP (Type 1) projects have a goal of increasing the number of STEM graduates, STEP projects vary substantially. Some focus on retention issues (as does our STEP project) while other focus on issues of recruitment, and indeed some few STEP project focus on both retention and recruitment.

On another dimension, some STEP project tend to be monolithic with one major program focus while others (such as ours) have multiple major thrusts addressing the broad target (retention in our case) from multiple directions. Another important difference between STEP projects is that many are cohort based programs while some are programs focus broadly on all STEM students in an entire college, such as ***EEES***. Our STEP project does indeed focus on all early engineering students rather than a more narrowly defined cohort within our engineering student population.

In our project we address two broad segments of our population: students who leave engineering because of academic difficulty and student who leave engineering in good academic standing but choose to “jump ship”. Our PAL/SI program is aimed to helping student to incrementally increase their GPA, which in many cases is enough to push them over the threshold to enable their admission to a major in the College of Engineering. Our CF program is aimed primarily to put a human face on “engineering” for early students by connecting them for interaction with engineering faculty.

The “take away” *interim* messages from our STEP project are as follows.

First, we are meeting our goal of increasing our college retention rate by ten percentage points. That of course is the good news. The bad news is that we cannot at this point do the necessary credit assignment to definitively rule in or rule out our programs for causing the improvement. Not only do we have a number of separate but interacting programs in our STEP project, the rest of our college environment has not (of course) stood still during the time of our project execution. One of our main challenges is to develop even more data resources than we currently have and create a systemic model of our environment that can at least give indicative results for credit assignment. Our path for systemic analysis lies in the construction of an over arching structural equation model (SEM). We hope to have initial results by late summer, 2013.

Second, results are promising for our Connector Faculty program. In addition to the hoped for impact on early engineering students, we also are seeing one effect that we should have anticipated, but did not. The existence of the CF program has given faculty in our College of Engineering an opportunity to reach out systematically to first year students and engage them on a human level. Our target was to encourage the early engineering students to better experience our faculty as "people" and engineering as a distinctly human enterprise. We find that, but we are also finding that the level of interest in teaching and learning for the early engineering students amongst our faculty has improved. Our top level take away is that our CF program is an exemplar of the adage "if we build it they will come". For us this is two dimensional: apparently both early students and engineering faculty embraced the program once in place. The faculty acceptance of the program in some form bodes well for sustainability of this program after our STEP project has run its course.

Third, the PAL/SI (peer mentoring) program in our STEP project presents a mixed picture. At LCC the program is effective. But at MSU the program is not effective. A fair amount of anecdotal evidence in wide circulation at NSF is along the lines that voluntary programs are not effective in STEP projects. Our experience in part supports this viewpoint and in part negates it. Why the difference between results at LCC and at MSU? We can only give conjectures at this point. But our conjecture is that at LCC because of the long standing SI programs, there is an acceptance by students at the institutional/cultural level that supports expansion to STEM areas. While at MSU concept-based tutoring such as PAL largely is (as opposed to quick in, quick out tutoring to answer a specific question) is manifestly not part of the student culture. In our remaining project time, we intent to explore this issue more fully. We have shown that there is not a simple answer to the question "Do voluntary programs work in STEP projects"? Rather the issue is environmentally sensitive. We intend to better understand the factors that *in general* influence success of voluntary programs in STEP projects.