

## **AC 2007-1503: AN ENGINEERING BRIDGE PROGRAM: IMPROVING THE SUCCESS RATE OF UNDERPREPARED STUDENTS IN ENGINEERING**

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# **An Engineering Bridge Program: Improving the Success Rate of Under-Prepared Students in Engineering**

## **Abstract**

In 2003, the College of Engineering at Wayne State recognized that a large proportion of its students entered the engineering program with placement into beginning or intermediate algebra. This is, in part, a result of the University's mission to be an institution of opportunity – providing access to all academically qualified students. Only a small group of these incoming students remained in the College of Engineering after 4 years. As a result, an Engineering Bridge Program was developed with the dual objective of: 1) providing students with the appropriate foundation in math and science to succeed in engineering; and 2) retaining students at the University, even if they opted to transfer out of the College.

The academic-year program was implemented in the Fall of 2004 and included both foundational skills in academics and “survival skills” for university and engineering study. The first cohort has now completed up to two years at Wayne State. The retention rate (within the University) and performance of freshmen within this group has been compared to a similar cohort that entered the College of Engineering in the Fall of 1999 and also placed into these lower level courses. The two-year retention rate for the Engineering Bridge students increased substantially compared to the 1999 cohort, from 53% to 62%.

After two years, the effect of this program on retention is promising. The Fall 2006 program has been enhanced and is anticipated to further increase continued enrollment. Assessment of the program will be ongoing, focusing on retention and academic performance.

## **Introduction**

As the economy changes and more emphasis is placed on jobs in technology-related industries, it falls to the higher education system to prepare students for careers in these fields. Many colleges of engineering, especially those with an urban mission, have recognized that a poor preparation in math and science reduces their students' chance for success in an undergraduate engineering program. However, for many students it is lack of opportunity – rather than lack of ability – that is the reason behind low math placement and substandard ACT or SAT scores.

Ideally, improving the preparation of students should be a joint project between universities and K-12 educators. However, this partnership can be complicated by the large number and diversity of the school districts from which a university attracts students. Therefore, the development of programs to meet the needs of all students interested in pursuing engineering, irrespective of the preparation they were able to obtain in high school, is imperative if colleges are to meet the educational needs of students and the educational goals of the community.

Wayne State University is a public, urban, research university located in the heart of Detroit. The University has a dual mission: to provide a top education to students backed by cutting-edge research; and to serve as a school of opportunity to many qualified students who may have no other options for a university education. In 2003, the College of Engineering assessed the relationship between math placement and the success rate of its entering freshmen. An evaluation of students entering the College of Engineering in 1999 demonstrated that over 60 percent of freshmen qualified for placement only in either basic or intermediate algebra. In addition, a significant number of transfer students also placed into these lower level courses. Of the freshmen in this 1999 cohort who entered Wayne State in one of the lower two math classes, only 25% remained in an engineering program at the university at the end of four years. Based on this data, it was determined that an Engineering Bridge Program could benefit students interested in engineering but who had not acquired the necessary background in math and science in high school.

Bridge programs for students in engineering have been championed at other institutions, with apparent success. Many focus on underrepresented groups<sup>6,7</sup> and are typically conducted during the summer prior to a student's freshman year.<sup>1,6,7</sup> Summer programs may focus on mathematics review<sup>1</sup> or on general preparedness for university and engineering study.<sup>7</sup> While many universities have implemented first-year engineering programs, most assume readiness for calculus among their incoming students. A much smaller number of bridge programs have been designed as semester-based or full academic year programs for underprepared students.<sup>2,5</sup> The inclusion of math, science, and basic academic skills for engineering in a contiguous program appears to be unusual.

The objectives of the Engineering Bridge Program at Wayne State are to:

1. Provide students interested in engineering with the foundational knowledge required to pursue their engineering program, thereby improving retention in the College
2. Assist students with determining within their first year at university if engineering is the appropriate educational path based on their interests and aptitudes

The latter objective is designed to improve retention of these students within the university as a whole, even if they elect to leave the College of Engineering. Many students entering Wayne State are not truly familiar with the field of engineering and may select it as their initial program based on the prospect of higher salaries or because a counselor or parent pushed them in that direction. A portion of these students will have a higher aptitude and affinity for other professional or liberal arts fields. It was therefore decided that the program would be classified as successful based on overall retention rates within the University, not simply retention in Engineering.

## **Engineering Bridge Program – Entrance Criteria**

It was determined that students entering the College of Engineering, either as freshmen or transfer students, who met one of the following criteria would be placed in the Engineering Bridge Program and required to complete its requirements:

- Placement into MAT 0993 (Beginning Algebra) or MAT 1050 (Algebra with Trigonometry) based on the University Mathematics Placement Examination
- Having earned a math and science gpa below 3.0 at the most recent institution, focusing primarily on courses below the level of college calculus (high school or college)
- Having earned a Math ACT score below 22 (or Math SAT score below 550) – freshmen only

## **Engineering Bridge Program – Curriculum**

The Engineering Bridge Program is designed to provide participating students with both the academic skills and the “survival” skills necessary to succeed as a student in an engineering program. Therefore, it includes traditional coursework as well as courses and activities targeted at developing students’ comfort with the university environment and services.

Research at other universities have identified key factors in improving the success of students in undergraduate engineering programs, beyond initial academic preparation. These include peer mentoring,<sup>4</sup> emphasis on basic academic skills,<sup>8</sup> and the establishment of a learning community. For many years, the Department of Mathematics at Wayne State has provided problem-solving workshops to supplement the didactic learning in its intermediate algebra and pre-calculus courses. These Pre-Emerging Scholars Program (PREP) and Emerging Scholars Program (ESP) workshops have been shown to substantially increase the success of students in mathematics through their team-based learning systems. This parallels the results seen more recently in at New Mexico State University, when a 2 credit supplemental instruction course was added to its intermediate and college algebra courses.<sup>3</sup> All Engineering Bridge students at Wayne State are required to take the PREP section of intermediate algebra, and the ESP section of pre-calculus is strongly recommended. The Engineering Bridge Program was designed to combine these learner-centered techniques with a strong foundation in the basic science, math, and English skills required of all engineering students.

As mentioned above, many universities have implemented a summer bridge program to give at-risk students a jump-start on their engineering studies. This model was not practical for students entering Wayne State University based on three factors. First, the majority of students at the university are required to work full-time during the summer in order to afford the next academic year’s tuition. A multi-week, full day program would not have allowed these students to participate. Second, the University’s rolling admissions policy allows students to apply and be accepted through the end of August, with classes starting in early September. The College was determined to develop a program that could include all students accepted to the program. Finally, the degree to which some students were behind in math, demonstrated by placement into beginning algebra, precluded the development of a summer program that would result in their being calculus-ready by the start of the fall semester.

The Bridge Program was first implemented in the Fall of 2004 with the following requirements:

Mathematics:

- Beginning Algebra (if required based on placement) [3 cr]
- Algebra with Trigonometry [7 cr]
- Elementary Functions (pre-calculus) [4 cr – 2 cr workshop recommended]

Science:

- Conceptual Physics with laboratory [4 cr]
- Chemical Skills and Reasoning [4 cr]

English:

- Basic Writing (if required based on placement) [4 cr]

Engineering:

- Introduction to the Engineering Profession [2 cr]
- Bridge Mentorship Program (*ad hoc*) – fall and winter semester

Students who placed out of beginning algebra, basic writing, or the introductory chemistry course, based on standard University placement tools, were not required to complete the first course in these subject areas. The Engineering Bridge advisor works closely with these students, who are in the minority, to select the appropriate courses to round out their schedules.

Students were expected to earn a minimum gpa of 3.0 in these 28 credits of coursework, with no grade lower than a C-, in order to move into one of the pre-professional programs in engineering. This gpa was chosen to demonstrate the strong foundation in math and science required to succeed in engineering, as well as a commitment to university studies. It also equates to the minimum required math and science performance of students in this level of coursework for direct admission into the pre-professional engineering program. The program is designed to be completed in a single, full-time academic year (2 to 3 semesters). Part-time students are encouraged to work with the Engineering Bridge advisor to develop a plan of work that allows them to progress through the Bridge Program at a reasonable pace.

Students were scheduled in block cohorts as much as possible, allowing them to form relationships with peers that could be used as both a support network and a study group. Students also participated in a mentorship program, in which small groups of students met weekly with a pair of upperclassmen or graduate students in the College of Engineering in order to discuss issues related to university adjustment and studying engineering. Finally, the College of Engineering advising staff followed these students closely, contacting all students who received substandard early assessment grades and requiring all Bridge students to meet with an advisor before registering for their second and subsequent semesters of classes.

After the first year of the program, it was identified that many Bridge students lacked some basic skills in areas of Internet usage, technical problem solving, and study skills. Therefore, for students entering the program in Fall 2005, an additional course “Skills for Success in Engineering” (BE 0991) was added to the curriculum. This course was developed in cooperation with the academic advising staff of the College of Engineering along with the University’s Academic Success Center. Lectures focused on the use of university academic systems (e.g. Pipeline and Blackboard<sup>TM</sup>); development of an academic plan of work; time management, note taking, and similar academic support skills; use of library research tools; and technical problem

solving. Objectives also focused on basic communication skills, teamwork, and professional ethics.

In addition, in Fall 2005, the mentorship program was changed from an *ad hoc* program to a scheduled, 0 credit course (BE 1001). This was done to make certain that students included this important part of the program in their weekly schedule and actively participated in the course. In the previous year, some students had indicated that they could not find a mentorship group with which they could meet due to scheduling conflicts, and they tended to then fall out of the program. A pass/fail grade is assigned based on attendance at the weekly mentorship sections, and students are required to satisfactorily complete two semesters of the course to advance to the pre-professional program.

The Skills for Success course was reviewed at the end of Fall 2005, and students were asked their opinions of the relevance of the class. Students were divided in their opinion – approximately 60 percent viewed it as key to their future success, while the other 40 percent felt that it addressed items that were remedial in nature and was below them. Based on these comments, the most basic skills (email, Internet, etc.) were separated into modules for the Fall 2006 version of Skills for Success in Engineering. This allowed students who required an education in these areas to work through the modules, often with assistance from their mentor, and for the lecture portion of the course to focus on higher-level skills. The student survey of the course from Fall 2006 demonstrated an increased satisfaction with the course. Average scores on achievement of the class objectives increased from 3.89 to 4.12 out of 5, while 94 percent indicated a positive impact on their future studies. In addition to this curriculum change, the grading on the course has been changed from pass/fail to letter grading so that students take the course more seriously – some students commented that this would impact their attention to the class.

As skills in communication and teamwork could only be touched on during the 1 credit, fall semester Skills for Success in Engineering course, a second, 1-credit course (BE 0992) was added for the winter semester for the first time during the 2006-2007 academic year. This second course includes more team-based projects and additional written communications through a focus on non-traditional careers for engineers. This course will be evaluated at the end of the Winter 2007 semester to determine its effectiveness. A second benefit of this course is that the few students who enter the Engineering Bridge Program in the winter semester can include an engineering course and the mentorship program in their first semester schedule. The modules on basic skills from the fall Skills for Success course are made available to these new students so that they can come up to speed as quickly as possible in their first semester.

At this point, no additional, major changes in the Engineering Bridge curriculum are anticipated. A balanced, two to three semester program of between 30 and 33 credits, depending on initial math placement, has been developed with both science/math and engineering courses in each semester. The curriculum consists of courses that currently support the program objectives or, based on program assessment, could be modified slightly to meet the program objectives. Continued semester-based and annual evaluation of the program will be conducted with the students as well as by the faculty.

## Results of Two Cohorts

The ultimate success of the Engineering Bridge Program will be determined based on graduation rates and gpa at graduation. However, that data will not be available for the first cohort until at least May 2010, given the average time to degree of more than 6 years for engineering students who start in lower-level math courses. The students who entered in 2004 and 2005 have been reviewed based on their status at the end of Fall 2006 semester as an initial indicator of program success. A summary of the data for students entering the Engineering Bridge Program for the 04-05 and 05-06 academic years is provided in Table 1.

**Table 1 – Students Entering the Engineering Bridge Program**

	2004 Cohort		2005 Cohort	
	Freshmen	Transfer	Freshmen	Transfer
<b>Count</b>	122	20	104	26
<b>Entering gpa</b>	3.11 (1.84 – 3.98)	2.52 (1.28 – 3.52)	3.08 (1.76 – 3.97)	2.72 (1.33 – 3.94)
<b>Math ACT</b>	19.9 (13 – 29)		19.4 (12 – 32)	
<b>Composite ACT</b>	19.3 (13 – 30)		19.1 (12 – 28)	

*Mean and data range for past educational records of students entering the Engineering Bridge Program.*

Students' records were evaluated through the end of the Fall 2006 semester to determine if they continued to register at the University and, if so, in what academic program. Students were then placed into one of four groups: Not Registered, Other WSU Program, Pre-Professional Engineering Program, and Engineering Bridge. While students were initially expected to complete the Engineering Bridge program in a single academic year, student transition to the university, work requirements, and other external factors have resulted in some students requiring more than one year to complete the program. This allowance is evaluated by the Associate Dean for Academic Affairs on an individual basis. In addition to the status of the students during the Fall 2006 semester, an evaluation was done on cumulative student gpa (all courses) and their performance in the Engineering Bridge Program. Evaluations were then made of the relationship between enrollment status and both entering characteristics and performance in the Bridge Program courses. This data is shown in Tables 2 through 4.

**Table 2 – Enrollment Status Fall 2006**

	<b>2004 Cohort</b>	<b>2005 Cohort</b>
<b>Not Registered</b>	58 (41 %)	35 (27 %)
<b>Other WSU Program</b>	38 (27 %)	25 (19 %)
<b>Engineering Bridge</b>	16 (11 %)	52 (40 %)
<b>Pre-Professional Engineering</b>	30 (21 %)	18 (14 %)

*Number of students in each enrollment category as through the Fall 2006 semester.*

**Table 3 – Academic Performance of Engineering Bridge Students**

	<b>2004 Cohort</b>		<b>2005 Cohort</b>	
	<b>Cum gpa</b>	<b>Bridge gpa</b>	<b>Cum gpa</b>	<b>Bridge gpa</b>
<b>Not Registered</b>	1.61 (0 – 3.9)	1.20 (0 – 3.89)	1.23 (0 – 3.59)	1.05 (0 – 4.0)
<b>Other WSU Program</b>	2.49 (0.8 – 3.8)	2.18 (0.44 – 3.88)	2.13 (0.66 – 3.35)	1.93 (0 – 3.33)
<b>Engineering Bridge</b>	2.32 (1.28 – 3.02)	2.25 (0.85 – 3.33)	2.39 (0 – 3.94)	2.22 (0 – 4.0)
<b>Pre-Professional Engineering</b>	2.91 (2.19 – 3.82)	3.39 (3.0 – 4.0)	3.08 (2.09 – 3.84)	3.43 (3.0 – 4.0)

*Mean and data range for university academic performance of students participating in the Engineering Bridge Program based on current enrollment status.*

**Table 4 – Enrollment Status and Entry Level**

	<b>2004 Cohort</b>					<b>2005 Cohort</b>				
	<b>Freshmen</b>			<b>Transfer</b>		<b>Freshmen</b>			<b>Transfer</b>	
	<b>#</b>	<b>Math ACT</b>	<b>Previous gpa</b>	<b>#</b>	<b>Previous gpa</b>	<b>#</b>	<b>Math ACT</b>	<b>Previous gpa</b>	<b>#</b>	<b>Previous gpa</b>
<b>Not Registered</b>	47	18.8 (13–27)	2.97 (1.9–3.9)	11	2.31 (1.3–2.9)	27	18.2 (12–26)	3.03 (2.2–3.7)	8	2.75 (2.2–3.7)
<b>Other WSU Program</b>	34	19.5 (14–29)	3.19 (2.4–3.9)	4	2.60 (2.3–3.1)	21	19.5 (14–25)	3.05 (2.0–4.0)	4	3.25 (2.3–3.9)
<b>Engineering Bridge</b>	13	18.9 (13–25)	2.90 (1.8–3.8)	3	2.90 (2.7–3.0)	40	19.8 (13–32)	3.10 (1.8–3.8)	12	2.51 (1.3–3.5)
<b>Pre-Professional Engineering</b>	28	22.5 (17–28)	3.39 (2.3–4.0)	2	2.90 (2.3–3.5)	16	20.4 (15–26)	3.16 (2.0–4.0)	2	3.4

*Enrollment status (mean and range) for Fall 2006 compared to past educational record (previous institution) for students in the Engineering Bridge Program.*

Interestingly, the rate of University retention at both 1 and 2 years is higher for FTIACs (First Time in Any College) compared to those students who transfer in from a 2-year or 4-year college. 61.5% of freshmen in the 2004 cohort remained at the University after 2 years, compared to only 45% of transfer students. The reason for this difference will require further investigation. As transfer students often have different needs than traditional freshmen, a modified Bridge Program – particularly with regards to survival skills – may be warranted for transfer students.

As indicated by the data in Table 4, it is not possible to predict which students will succeed and remain either in the College or at the University based strictly on entry statistics. While students who have moved into the pre-professional program have a higher average value for both previous gpa and Math ACT scores, the range of the data overlaps significantly. Both in terms of ACT Math score and gpa, there are students who enter with poor academic records (e.g. Math ACT = 15, Previous gpa = 2.3) and succeed in the Engineering Bridge Program, moving into the pre-professional engineering program of their choice. These are the students who demonstrate the benefit of the continued role of the College of Engineering and Wayne State University as an institution of opportunity, providing students with the chance to demonstrate their academic ability.

### **Comparison to a Previous Cohort**

The initial cohort used for comparison with Engineering Bridge students are freshmen who entered the College of Engineering in the Fall of 1999. This group was selected for the assessment in 2003 as they theoretically could have completed their degree programs by May of that year, when the evaluation was made.

In Fall 1999, 136 freshmen students entered the College of Engineering. Of these, 61% placed into beginning algebra or algebra with trigonometry. These “Bridge Eligible” students had an average Math ACT score of 20.0 and an average incoming gpa of 3.11. This compares well with the average record of the freshmen entering the Bridge Program in 2004 and 2005.

Four years later (Winter 2003), only 24% of freshmen who had placed into one of these two classes remained enrolled in an Engineering Program, while an additional 14% were enrolled in another program at the University. For a more parallel analysis to the current cohorts, retention at the end of one and two years can be examined (Table 5).

**Table 5 – Total Loss of Fall 1999 “Bridge Eligible” Freshmen**

	<b>After Year 1</b>	<b>After Year 2</b>
<b>Number</b>	19	39
<b>Percentage Loss</b>	23%	47%
<b>Cumulative gpa</b>	0.91 (0 – 3.65)	1.49 (0 – 3.74)

*Total number and cumulative gpa (mean, range) for students who placed into lower-level math courses (MAT 0993 or MAT 1050) and DID NOT return to the University after the first and second years of their programs. Note that the Year 2 numbers include the 19 who left the University after their first year of enrollment.*

For freshmen who entered the College of Engineering in 1999 and placed into either MAT 0993 or MAT 1050, 23% had opted to leave the University within the first year. This compares closely with the 26% of the freshmen in the Fall 2005 Bridge cohort (27/104) who did not register during the 06-07 academic year. The slight increase in loss rate may be due to the fact that students in the Bridge Program are now required to take a more rigorous set of courses in their first year than those who previously placed into the first math courses. In the past, students generally filled their schedules with general education courses rather than technical courses. However, the average cumulative gpa of freshmen not returning to the University after one year is actually higher within the 2005 Engineering Bridge cohort (1.23) compared to the 1999 “Bridge Eligible” cohort (0.91).

Only 53% of the Fall 1999 freshman cohort remained at the University at the end of two academic years and continued to enroll during the Fall 2001 semester. For the Engineering Bridge students who began with the Fall 2004 cohort, almost 62% (75/122) of the freshmen remained enrolled in the University through Fall 2006 (2 years). This is a full 9-point increase in retention rate. The limited number of cohorts included to date does not yet allow for statistical assessment of these retention rates to determine if the increased retention is statistically significant or if it will be maintained – such an analysis will be conducted in the future.

## **Discussion**

The Engineering Bridge program is still in its infancy and only with Fall 2006 has it developed into what is anticipated to be its final curriculum. While the true success of the Bridge Program will only be seen by examining 4-year and 6-year graduation rates, along with student gpas, the initial evaluation after the first two years of the program is promising. 9% more of the “Bridge Eligible” freshmen remained at the University after two academic years when comparing the cohort of students who entered in Fall 1999 and Fall 2004 (53% vs. 62%). It will be necessary to continue to track the Bridge cohorts to see if the increase in retention rate holds through the 4 and 6-year time points and is consistent for new groups of students. As the program has been enhanced since Fall 2004, it is hoped that the positive impact may actually increase.

Advising and communication systems, especially relating to Orientation, are being improved to ensure that students entering the College of Engineering have their placement results early

enough to allow for proper registration. The results of the first two cohorts of students will also provide insight into how much of a “second chance” students should be given who receive a substandard grade in one or more of their Bridge classes. In general, students with a single failing grade are allowed to remain in the Bridge Program and repeat that course, while students with a weaker record are required to meet with the Associate Dean for Academic Affairs to assess whether or not they will be allowed to continue and under what conditions. Identifying predictive factors for success, in order to separate out those students who are not likely to succeed from those who simply have had a severe transitioning problem during the first semester, will benefit both students and the program in the long run.

The College of Engineering feels that early advising of interested engineering students is paramount, rather than allowing them to build their foundation within the College of Liberal Arts and Sciences, as many engineering program requirements are more restrictive than other units in the University (e.g. general education course selection). As such, students have for many years been accepted to the College based solely on acceptance to the University. While, the success rate of under-prepared students has been very low, some of the students who enter at the lowest level of math have gone on to graduate as members of Tau Beta Pi, indicating that it is preparation, and not ability, that affected their initial academic program as they enter the university.

The statistics demonstrate that some of the students who do not continue at Wayne State are not making that decision based on poor academic performance – the range of grade point averages for non-returning students runs from a low of 0.0 to a high of 4.0. Some students use a strong first year in Wayne State programs as a stepping-stone to universities outside of the metro-Detroit area. While these students are not included in university or college retention numbers, and there is no current system to account for graduation rates of students who transfer out of the University, it is hoped that the Engineering Bridge Program has provided them with a foundation on which to build at any college or university.

## **Conclusions**

In conclusion, the Engineering Bridge Program at Wayne State University provides under-prepared students with an opportunity to enter engineering study that may be denied to them if strict admissions standards to the College are implemented. This allows the College to both maintain standards within its engineering programs and meet its urban mission as a university of opportunity for students. The initial success of the program, as evidenced by the increased 2-year retention, provides a strong impetus to continue the program in support of current and future students.

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