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The Wright State Model for Engineering Mathematics Education: A Longitudinal Study of Student Perception Data

Prof. Nathan W. Klingbeil, Wright State University

Nathan Klingbeil is a Professor of Mechanical Engineering and Dean of the College of Engineering and Computer Science at Wright State University. He is the lead PI for Wright State's National Model for Engineering Mathematics Education, which has been supported by both NSF STEP Type 1 and CCLI Phase 3 awards. He has received numerous awards for his work in engineering education, and was named the 2005 Ohio Professor of the Year by the Carnegie Foundation for the Advancement of Teaching and Council for Advancement and Support of Education (CASE).

Anthony Bourne, Wright State University

Tony Bourne is the Director of Enrollment Management for the Wright State University College of Engineering and Computer Science. He is a Wright State alumnus were he received a BA in Economics and completed his PhD in Engineering Spring 2014. He also holds an MPA from Walden University. His graduate research focused on interventions that increase student retention in open enrollment schools like Wright State. Tony worked several years in workforce development and education outside Wright State starting there in 2007, when he was hired as an enrollment adviser for the Department of Electrical Engineering; he later served as the Assistant to the Chair. He then transitioned to the Dean's Office and served as the data analyst and co-op coordinator for the college before transitioning to his current position.

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Abstract

The inability of incoming students to advance past the traditional first-year calculus sequence is a primary cause of attrition in engineering programs across the country. As a result, this paper summarizes an NSF funded initiative at Wright State University to redefine the way engineering mathematics is taught, with the goal of increasing student retention, motivation and success in engineering. The approach involves the development of EGR 101 - a first-year engineering course replacing traditional math prerequisites for core sophomore engineering courses - along with a more just-in-time structuring of the required calculus sequence. Since its inception in Fall of 2004, the impact of the Wright State model on student retention, motivation and success has been widely reported. Last year's paper included results of a longitudinal study of program impacts at Wright State University, including student performance in calculus, student performance in core engineering courses, and ultimate graduation rates. The current paper will provide a longitudinal analysis of student perception data, as measured by end-of-course surveys. In particular, the extent to which reported increases in student motivation and self-efficacy have contributed to the previously reported increases in ultimate graduation rates will be investigated.

The Wright State Model

It is well known that student success in engineering is highly dependent on student success in math, and perhaps more importantly, on the ability to connect the math to the engineering[1-6]. However, first-year students typically arrive at the university with virtually no understanding of how their pre-college math background relates to their chosen degree programs, let alone their future careers. And despite the national call to increase the number of graduates in engineering and other STEM disciplines[7] , the inability of incoming students to successfully advance past the traditional freshman calculus sequence remains a primary cause of attrition in engineering programs across the country. As such, there is a drastic need for a proven model which eliminates the first-year mathematics bottleneck in the traditional engineering curriculum, yet can be readily adopted by engineering programs across the country. Such is the focus of this work.

Figure 1. The Derivative Lab

The Wright State model begins with the development of a novel first-year engineering math course, EGR 101 Introductory Mathematics for Engineering Applications. Taught by engineering faculty, the course includes lecture, laboratory and recitation components. Using an application-oriented, hands-on approach, the course addresses only the salient math topics actually used in core engineering courses. These include the traditional physics, engineering mechanics, electric circuits and computer programming sequences. The EGR 101 course replaces traditional math prerequisite requirements for the above core courses, so that students can advance in the curriculum without first completing a traditional first-year calculus sequence. The Wright State model concludes with a more just-in-time structuring of the required math sequence, in concert with college and ABET requirements. The result has shifted the traditional emphasis on math prerequisite requirements to an emphasis on *engineering motivation for math.*

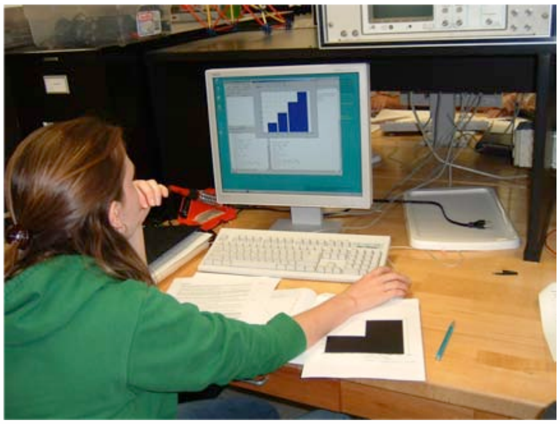

Figure 2. The Integral Lab

The EGR 101 lecture sections are completely driven by problem-based learning, while the laboratory and recitation sections offer extensive collaborative learning among the students. As such, the course is strongly supported by the literature on how students learn[8-12]. Excerpts from the EGR 101 laboratory are shown in Figures 1-2. Indeed, physical measurement of the derivative as the velocity in free-fall (Fig. 1), or of the integral as the area under the force-deflection curve (Fig. 2), provides a much greater conceptual understanding of the mathematical concepts than classroom lecture alone.

The Wright State model was first implemented in Fall of 2004, and its effect on student retention, motivation and success in engineering has since been widely reported[13-27]. In particular, results of a longitudinal study have shown that the program has substantially mitigated the effect of incoming math preparation on student success in engineering across the entire range of incoming ACT math scores, which has more than doubled the average graduation rate of enrolled students.[13,14] Moreover, it has done so without watering down the caliber of graduates, who have actually enjoyed a slight (but statistically significant) increase in graduation GPA. Finally, the approach has been shown to have the greatest impact on members of underrepresented groups, including both women and minorities. Last year's paper concluded with a brief look into the role of student motivation and self-efficacy, which is the subject of further investigation herein.

Longitudinal Study of Student Perception Data

While EGR 101 was designed to increase student motivation and perceived chance of success (i.e., self-efficacy) in both math and engineering, insight into their relative roles can be gained by a longitudinal analysis of EGR 101 post-course student survey data. Specifically, students were asked to rank the following statements on a scale of 1 (strongly disagree) to 5 (strongly agree), with 3 being neutral:

Q1. This course has increased my motivation to study engineering.
Q2. This course has increased my chances of success in engineering.
Q3. This course has increased my motivation to study math.
Q4. This course has increased my chances of success in future math courses.

Survey questions Q1 and Q3 address the extent to which the course increased student motivation, while questions Q2 and Q4 address the extent to which the course increased student self-efficacy.

The population considered herein includes all new direct-from-high-school students from the incoming classes of 2004-2006 who took the EGR 101 course and completed the end-of-course survey, and for whom both ACT math scores and high school GPA's were available. As such, this total population of 151 students represents a sizeable subset of the population considered in last year's paper[13]. For all results presented herein, statistical significance testing was conducted using the JMP software package.

A comparison of average responses to survey questions Q1-Q4 by students who ultimately did and did not graduate with degrees in engineering is shown in Figure 3.

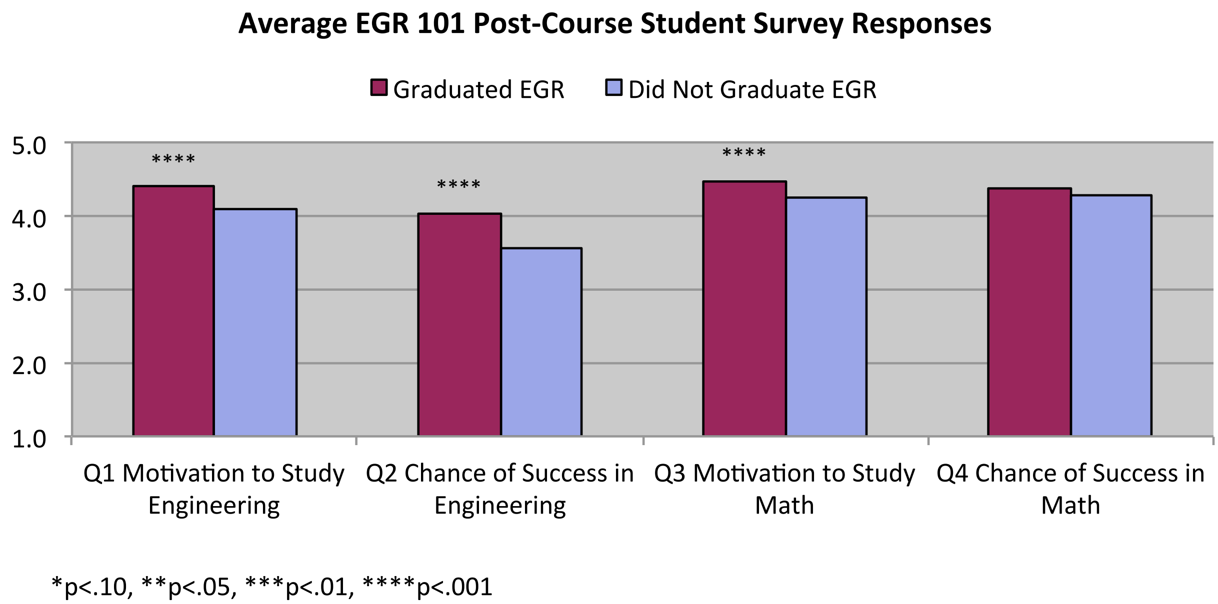

Figure 3. Comparison of EGR 101 Post-Course Survey Responses for Students who Ultimately Did and Did Not Graduate with Degrees in Engineering

Clearly, the EGR 101 course had a stronger impact on both the motivation and self-efficacy of students who ultimately graduated, as compared to those who did not. The difference was statistically significant for all but question Q4, to which students in both categories had an equally positive response.

Given that the population of Wright State engineering students spans the full range of American high school graduates, it is useful to sort the impact of EGR 101 by "caliber" of incoming student. Two widely accepted measures of academic caliber for incoming engineering students are ACT math scores and high school GPA. While a high ACT math score generally indicates strong academic ability, a high GPA generally indicates strong student motivation and work ethic. While engineering educators all appreciate the former, most would agree that the latter is more critical to student success in engineering.

A comparison of average survey responses by students with ACT math scores above and below the mean is shown in Figure 4, while a comparison by students with high school GPA's above and below the mean is shown in Figure 5.

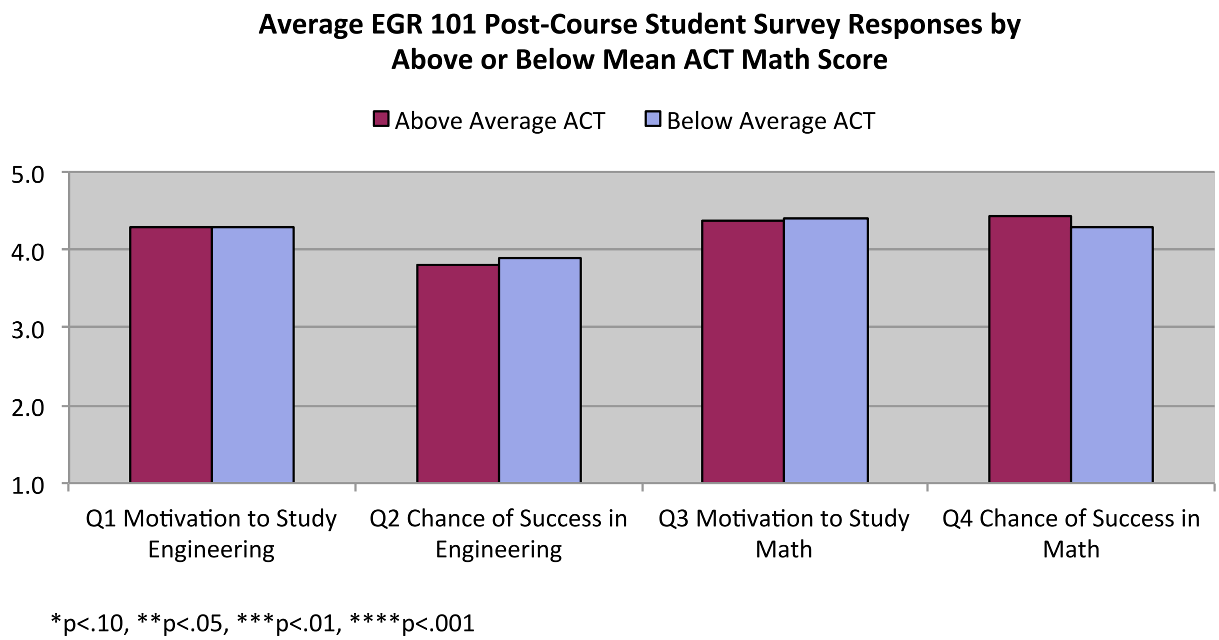

Figure 4. Comparison of EGR 101 Post-Course Survey Responses for Students with Above and Below Average ACT Math Scores

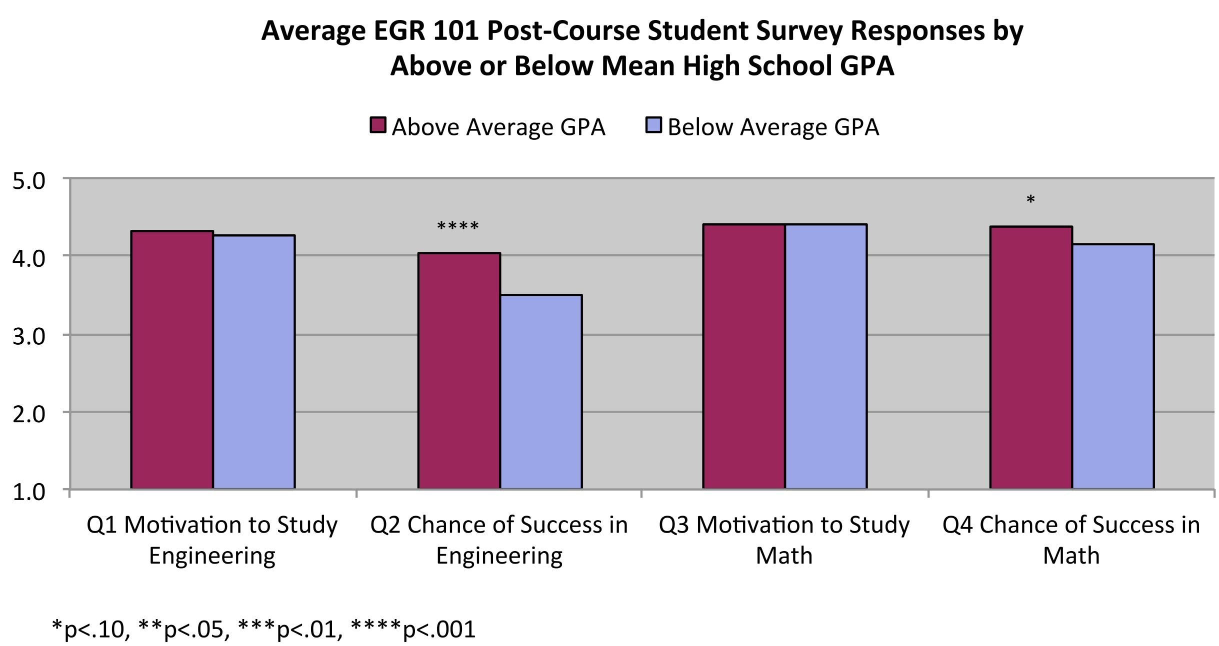

Figure 5. Comparison of EGR 101 Post-Course Survey Responses for Students with Above and Below Average High School GPA

As shown in Figure 4, there was no statistically significant difference in survey responses between students with high ACT math scores and those with low ACT math scores. The average response to question Q1 was nearly identical. However, Figure 5 indicates a statistically significant difference in response to question Q2 – self-efficacy in engineering – between students with high and low high school GPA's. Specifically, the self-efficacy of students with above average high school GPA's (i.e., the hard workers) was more strongly influenced by EGR 101 than that of students with below average high school GPA's. It is not surprising that question Q2 is the one most highly correlated to ultimate graduation in engineering. The hard workers make it through – at least in part, because EGR 101 helps them *believe* they can do it.

The above conclusion is especially important for females. Women who enroll in engineering are typically hard workers with above average high school GPA's. But they do not necessarily believe that they belong in the engineering program – particularly after they walk into a first-year classroom filled with men. Results of the EGR 101 student survey sorted by gender are shown in Figure 6.

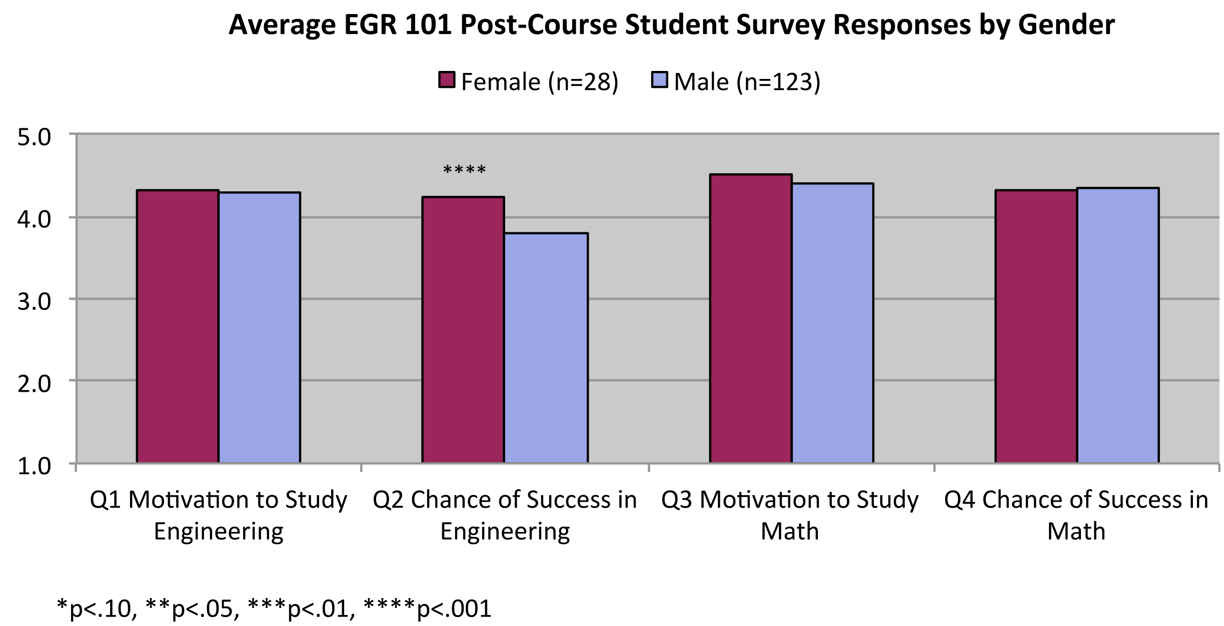

Figure 6. Comparison of EGR 101 Post-Course Survey Responses by Gender

Interestingly, the only statistically significant difference between the survey responses of women and men was for question Q2 – self-efficacy in engineering. Females felt more strongly that EGR 101 had increased their chances of success in engineering than did males. It helped them believe that they had chosen the right major, and the result was an even greater impact on ultimate gradation rates[13,14]. Given that 90% of the female population in this group had an above average high school GPA, the results of Figure 6 are both similar to and consistent with those of Figure 5.

The above roles of ACT math and high school GPA, including the associated correlation with gender, suggest that the range of incoming students might best be quantified using a combination of the two. This has led to the development of the Academic Performance Commitment Matrix (APCM), which is discussed in greater detail by Bourne et al. in a separate paper.[28]

In brief, the APCM characterizes students in terms of the following four categories: Support and Purpose Seekers, having below average ACT scores and below average high school GPA; Purpose Seekers, having above average ACT scores and below average high school GPA; Support Seekers, having below average ACT scores and above average high school GPA; and Achievers, having above average ACT scores and above average high school GPA.

In order to further investigate the roles of motivation and self-efficacy on ultimate graduation rates, average responses to student survey questions Q1 and Q2 sorted by APCM group are shown in Figures 7 and 8, respectively.

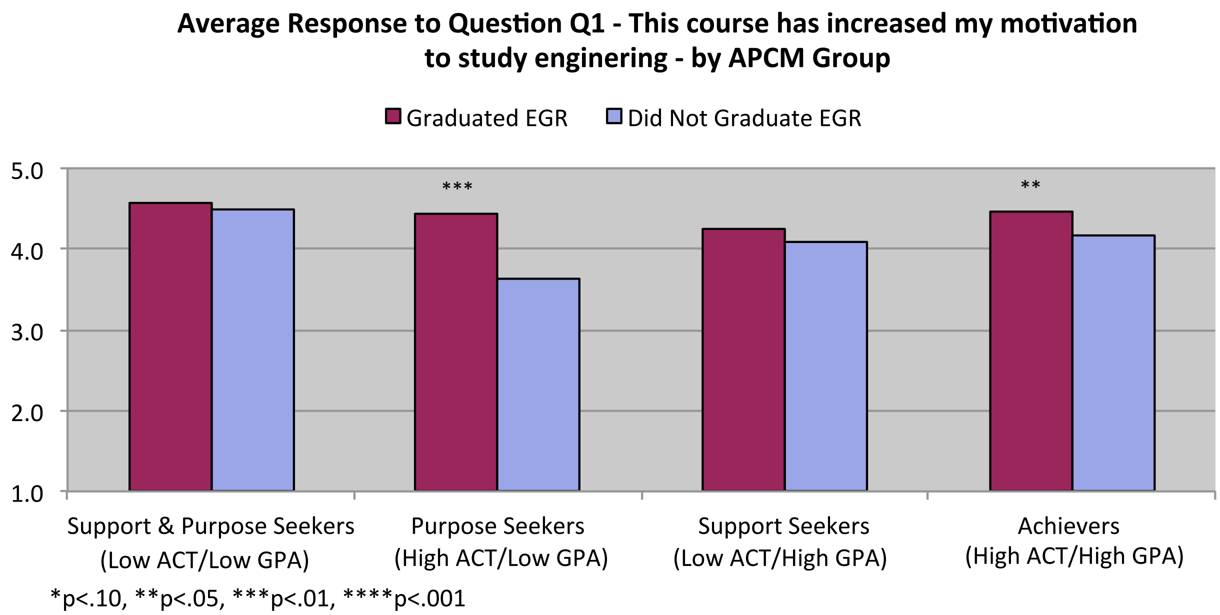

Figure 7. The Role of Motivation by APCM Group

As shown in Figure 7, students who ultimately graduated in engineering indicated that EGR 101 increased their motivation to study engineering more strongly than students who ultimately did not graduate, which is consistent with the results of Figure 3. The statistically significant difference was for the Purpose Seekers and the Achievers (i.e., high ACT students). This result is not surprising, in that students with high ACT scores are typically in greater need of *motivation* than they are of academic ability. This is particularly true for the Purpose Seekers, who have plenty of academic ability but lack the motivation and work ethic required to deliver a high GPA. For those who ultimately graduated, the results of Figure 7 suggest that EGR 101 provided (or at least contributed to) the motivation they needed.

As shown in Figure 8, students who ultimately graduated in engineering indicated that EGR 101 increased their chances of success in engineering (i.e., self-efficacy) more strongly than students who ultimately did not graduate, which is also consistent with the results of Figure 3. Again, the difference was statistically significant for both the Purpose Seekers and the Achievers (high ACT students). That said, the results also suggest that EGR 101 had a strong impact on the efficacy of *all* students who ultimately graduated, with an increasing trend from left to right on the APCM continuum. The results for the Support Seekers (low ACT/high GPA) are particularly noteworthy. While there was no statistically significant difference in the responses of those that did or did not graduate in engineering, the average response of the Support Seekers was higher than nearly all other groups. Only the Achievers who ultimately graduated indicated a stronger response. As discussed by Bourne et al., students with high GPA's generally have a higher overall commitment to college, and therefore higher graduation rates; however, those with low ACT scores (i.e., the Support Seekers) also tend to have lower self-efficacy[28]. As such, the Support Seekers tend to be hardworking and conscientious, but lack the belief that they can be successful in engineering. As such, the support seekers stood to gain the most self-efficacy from EGR 101, which was apparently the case even for those who ultimately did not graduate in engineering. It should be noted that most of these students did ultimately graduate in another major.

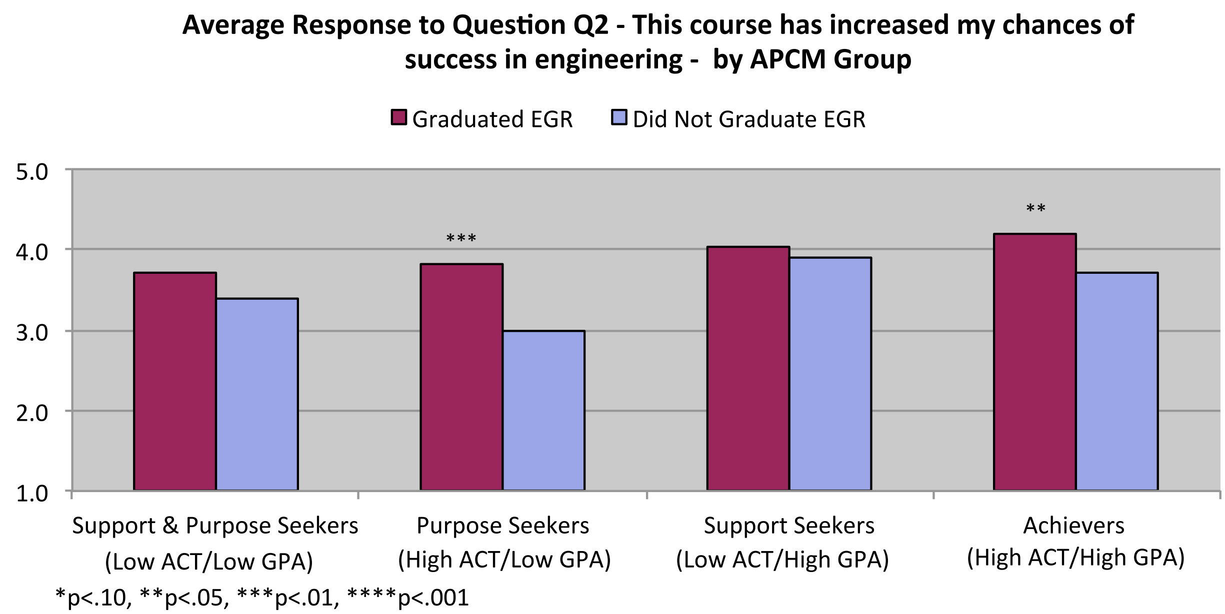

Figure 8. The Role of Self-Efficacy by APCM Group

Conclusion

This paper has summarized an NSF funded curriculum reform initiative at Wright State University to increase student success in engineering by removing the first-year bottleneck associated with the traditional freshman calculus sequence. The approach involves the introduction of EGR 101, a first-year engineering math course replacing traditional math prerequisites for core sophomore engineering courses, along with a more just-in-time structuring of the required calculus sequence. Since its inception in Fall of 2004, the program has had an overwhelming impact on engineering student retention, motivation and success at Wright State University. The approach is designed to be readily adopted by any institution employing a traditional engineering curriculum, and is now under consideration by dozens of institutions across the country. Results of a recent longitudinal study suggest that the Wright State approach has the potential to *double* the number of our nation's engineering graduates, while both maintaining their quality and increasing their diversity. The current paper has provided a look into the roles of student motivation and self-efficacy through a longitudinal analysis of EGR 101 post-course student survey data. Overall, results suggest that the impact of EGR 101 on student motivation and self-efficacy has indeed contributed to the increased graduation rates previously reported, with the greatest impact on the student groups who stood the most to gain. In regard to motivation, this includes the Purpose Seekers – students with high ACT scores and low high school GPA's – who are in greater need of motivation than academic ability. In regard to self-efficacy, this includes women in engineering, whose survey responses were significantly stronger than those of men. This also includes the Support Seekers – students with above average high school GPA's but low ACT scores – who tend to have the required work ethic but do not necessarily *believe* they can be successful in engineering.

Program Information

More information on the Wright State model (including all course materials for EGR 101) can be found at www.cecs.wright.edu/engmath/. Textbook information is available at www.wiley.com/college/rattan.

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