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The Diversity of STEM Majors and a Strategy for Improved STEM Retention

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A discussion of the definition of STEM for college majors, a summary of interest in the STEM majors as freshmen enter college and a strategy for improved student retention based on the diversity of the STEM disciplines.

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INTRODUCTION

Much has been written about the need for more science, technology, engineering and math (STEM) majors in colleges and the workplace. Often the discussions have centered on the need for filling the pipeline for engineers (Johnson and Sheppard, 2002; NAS, 2005; Brophy et al. 2008). President Obama has recently focused national support for STEM education (Obama, 2009). This includes increasing interest in STEM careers among high school students. With the current national attention on STEM education, I had an interest in understanding student interest in engineering majors relative to all STEM majors and whether there was increased interest in the STEM college majors as students enter college.

There is also a call for increased accountability for colleges helping students to be successful in completing a college degree in the STEM disciplines (Padro, 2010). In a recent NCES report, the six-year graduation rate of students who started college in 1995 as STEM majors is only 35% (Chen and Weka, 2009). Statistics on graduation rates may differ from study to study but, unfortunately, this statistic is representative and indicates the need for more effective strategies and policies to help STEM students complete their degrees. We know that much of the attrition from STEM and, especially engineering, occurs in the first year of college.

This paper looks at student interest in the STEM disciplines using the UCLA Higher Education Research Institute (HERI) publications on their CIRP survey and then discusses a strategy for improving student retention of STEM majors, especially in the first year of college.

Diversity of STEM Majors

Although diversity is often discussed in terms of racial diversity, there are many ways of thinking of diversity in our higher education system. (Dey, 2008). One of these ways is with respect to the diversity of STEM majors in our colleges. To better understand this diversity, national survey results were used to look at the distribution of students in the various STEM majors as they enter college matriculating freshmen in bachelor degree programs.

Importance of Assessments for Student Success

With the demand for additional scientists and engineers in the workforce, much more effective strategies are needed to help students complete their STEM major studies and have successful careers in the STEM disciplines. Key to a significantly higher graduation among STEM majors is a successful transition from high school through the first year of college. Any successful strategy requires a good assessment of the predictors for STEM student success and retention. Predictors for student success can be different for various STEM majors and will impact a successful strategy for student success. This paper discusses an assessment approach based on STEM student research, which identifies nine pillars for student success. Suggestions for strategies for student success will also be presented.

INTEREST IN STEM MAJORS IN COLLEGE

When STEM student retention in college is discussed, STEM refers to majors with a strong focus on science, technology, engineering or mathematics. To understand the diversity of the STEM majors, it is instructional to review the results of a national survey of college students and the students' interest in their college major. One such survey is the UCLA/Higher Education Research Institute (HERI) CIRP (Cooperative Institutional Research Program) survey. College freshmen throughout the United States have completed this survey for more than 40 years with HERI publishing the survey's annual results.

The CIRP survey asks students to indicate their probable (undergraduate) field of study as they enter college (HERI, 2009). The survey results from this question can be used to quantify the percent of college-enrolled students who are interested in a STEM major in college. Responses from students enrolled in all bachelor's degree programs of participating colleges are included.

Table 1 summarizes the STEM majors into the broad categories covered in the science, technology, engineering and mathematics (STEM) fields. The summary compares the results for 1990, 2000, and 2009 to understand increasing or decreasing interest in the STEM categories since 1990.

For Table 1, the following definitions of STEM majors were used based on possible responses on the CIRP survey (HERI, 2009). Majors are included with a concentration of mathematics, science, engineering or technology courses in the college curricula.

- Biological sciences includes: all the biological sciences, agriculture and forestry.
- Medical professional (science) includes: medicine, dentistry, veterinary medicine, nursing, and pharmacy.
- The math and physical sciences include: mathematics, astronomy, atmospheric science, chemistry, earth science, marine science, and physics and other physical sciences.
- Engineering includes: all engineering majors and architecture.
- Engineering technology includes: drafting or /design, electronics, mechanics, computer science and data processing or computer programming.
- Health technology includes medical, dental and lab technology.
- Medical therapy includes occupational, physical and speech therapy and is included here as a technology. (Medical therapy sometimes is excluded as a STEM major. For this summary, it is included because of the large number of courses required in the biological sciences.)

Note that in some definitions of STEM, the social sciences are included. Consistent with the NCES report on STEM issues (Chen and Weko, 2009), the social sciences are not included in this definition of STEM.

Table 1: Percent of Students With a Probable Major in a STEM Field Based on the HERI CIRP Survey Results for Entering College Freshmen at Educational Institutions Granting Bachelor's Degrees in the United States [1]

Probable Major Field	1990	2000	2009
Biological Sciences	5.7	7.3	10.4
Medical Professional (Science)	7.4	7.3	9.9
Math and Physical Sciences	2.8	2.6	3.4
Engineering	10.8	9.8	10.3
Engineering and Computer Technology	2.7	5.6	2.0
Health Technology (lab, med, dental)	0.7	0.4	.5
Medical therapy (technology)	2.3	1.9	2.3
Total STEM	**32.4**	**34.9**	**38.8**

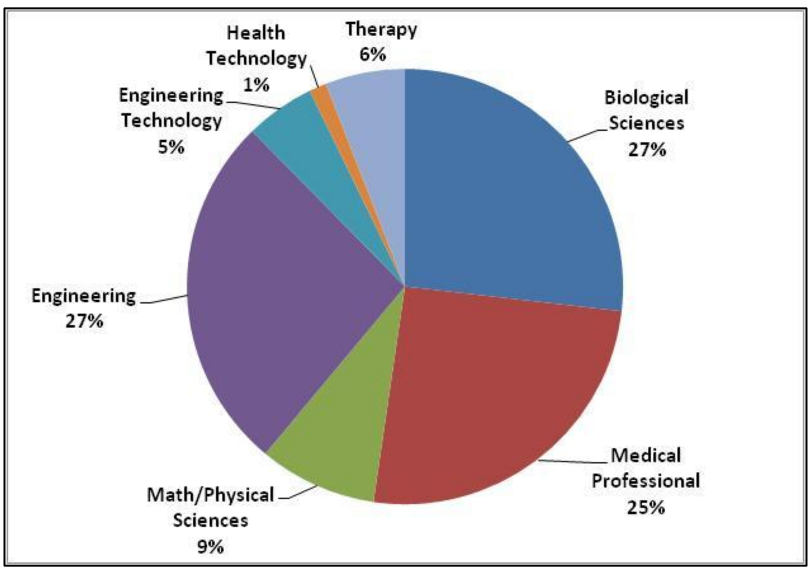


Figure 1: Percent Interest in STEM by Each STEM Category for 2009.

[1] Based on UCLA/HERI References: "The American Freshman: Forty Year Trends" and "The American Freshman: National Norms Fall 2009"

Relative Interest in STEM

The percent of students pursuing a STEM major at educational institutions with a bachelor's degree program or higher has increased by 20% from 32% in 1990 to 39% in 2009. (see Total STEM, Table 1). Based on the results in Table 1, the STEM majors are dominated by three general STEM categories (see Figure 1):

- *Biological sciences*
- *Medical professional*
- *Engineering*

Interest in the biological science majors and medical professional majors has grown while interest in the engineering majors has stayed constant between 1990 and 2009.

Figure 1 shows the relative percent interest in STEM by each STEM category for 2009. More than 50% of the interest in STEM majors comes from students who are interested in the biological sciences and the medical professions. *Interest in engineering constitutes only about one-quarter of the total interest in all STEM majors.* In 2009, 10.3% of the students responded that engineering was their most probable major while 38.8% of the students reported that their most probable major was in the STEM field, yielding a 27% relative percent of total interest in STEM. Note that only 3% of the freshmen are interested in a math and the physical sciences major, one that contributes significantly to space and technology innovation. These facts make it even more important that colleges develop strategies that recruit and retain (and excite) students in the engineering and physical sciences majors.

Differences in Interest in STEM Majors by Gender

Because of the ever-present interest in attracting women to engineering and the availability of CIRP survey summaries by gender, Table 2 and 3 disaggregate the results from Table 1 to present gender differences. Table 2 displays the survey results for freshman women while Table 3 displays the survey results for freshman men (Pryor, et al., 2009). Due to a 50% increase in interest in the medical professions and the doubling of interest in the biological sciences, the percent of women interested in a STEM major has increased by 35% from 26% in 1990 to 36% in 2009. Thus, Figure 2 clearly shows that the percent of female students interested in a STEM major has increased compared to male students. In the same time period, the percent of men entering college who are interested in a STEM major has increased by 9% to 43% of all freshman males.

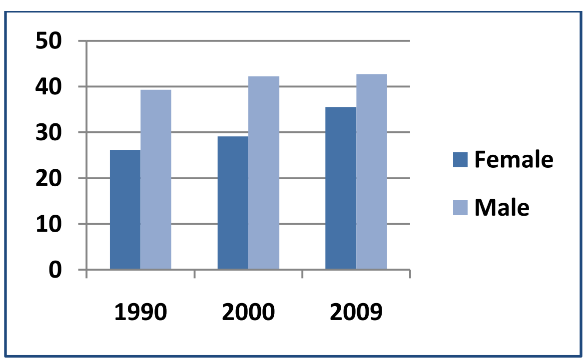


Figure 2: Percent of Female and Male Freshmen Interested in a STEM Major Using the CIRP Survey.

Table 2: Percent of Female Students With a Probable Major in a STEM Field Based on the HERI CIRP Survey Results for Entering College Freshmen at Educational Institutions Granting Bachelor's Degrees in the United States.

Probable Major Field	1990	2000	2009
Biological Sciences	5.1	7.9	11.0
Medical Professional (Science)	9.5	10.0	13.8
Math and Physical Sciences	2.1	2.1	2.9
Engineering	4.0	3.7	3.8
Engineering and Computer Technology	1.7	2.2	0.6
Health Technology (lab, med, dental)	0.8	0.6	0.6
Medical therapy (technology)	3.0	2.6	2.8
Total STEM	26.2	29.1	35.5

Table 3: Percent of Male Students With a Probable Major in a STEM Field Based on the HERI CIRP Survey Results for Entering College Freshmen at Educational Institutions Granting Bachelor's Degrees in the United States.

Probable Major Field	1990	2000	2009
Biological Sciences	6.1	6.4	9.7
Medical Professional (Science)	4.7	4.0	4.9
Math and Physical Sciences	3.9	3.0	4.3
Engineering	18.7	17.4	18.3
Engineering and Computer Technology	3.9	10.0	3.5
Health Technology (lab, med, dental)	0.6	0.3	0.4
Medical therapy	1.4	1.1	1.6
Total STEM	39.3	42.2	42.7

In the 2009 entering freshman class, interest in the biological sciences was about 10% for both male and female students. The substantial difference by gender is in the percent of students interested in the medical professions versus engineering (highlighted areas, Tables 2-3).

For 2009, 14% of females entering college were interested in a medical professional major and only 4% expressed an interest in an engineering major. By contrast, 18% of the male students indicated that their probable major would be engineering and only 5% indicated an interest in a medical professional major. Despite the major efforts to attract high school girls to engineering, the percent of women interested in engineering remained the same at 4% from 1990 through 2009.

When the percent of students interested in engineering is compared to the overall STEM interest percent, *engineering represents 11% of the freshman females interested in a STEM major while engineering represents 43% of the freshman males interested in a STEM major*.

Tables 2 and 3 highlight the reason that the engineering community is focusing on increasing the number of female students in engineering as well as the percent of minorities. Nationally, only 20% of the graduates in engineering are women (De Cohen, 2009). The data presented in Tables 2 and 3 is consistent with this percentage (4% female and 18% male interested in engineering).

In summary, the percent of female students entering college interested in a STEM major is closing the gap compared to the interest for male students. But female students are much more attracted to the biological sciences and the medical professional majors than to engineering and the physical sciences.

Little Difference in Interest in STEM by Race

A recent HERI research brief provided insight into the percent of under-represented racial minority (URM) students interested in a probable STEM major as they enter college. As students are entering college, the same percent of URM students as non-URM students are expressing an interest in the STEM disciplines. For 2009, 34.1% of the URM students entering a bachelor's degree program indicated that their most probable major would be a STEM major, while 34.3% of the non-URM students (white and Asian Americans) indicated that their most probable major would be a STEM major (HERI, 2010).

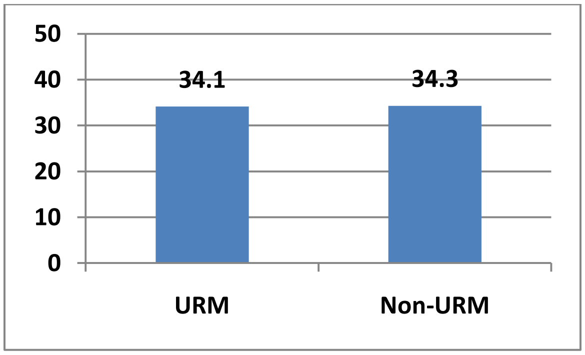


Figure 3: Percent of URM and Non-URM Students Expressing an Interest in a STEM Major. Source: HERI (2010).

In this HERI research brief, STEM was defined differently than for Tables 1-3. In HERI's racial group statistics, STEM was defined without the engineering technology majors, architecture, forestry, therapy and engineering technology (computer science was included). For comparison purposes, using the same STEM categories as HERI used in their research brief, the 2009 percent of female students interested in a STEM major would be 31.9%; the percent of male students interested in a STEM major would be 38.7% .

SUMMARY: THE DIVERSITY OF STEM MAJORS

A review of Tables 1-3 and Figure 1 shows diversity and breadth in the majors covered in the STEM disciplines. The biological sciences and medical professional majors are more focused on biology and medicine, while engineering is more focused on math, technology and analytical thinking. The high school courses required to achieve success in the biological sciences will be different college preparatory courses than for engineering and the physical sciences.

From Figure 1, more than 50% of the interest in STEM majors is in the biological sciences and medical professional majors. Thirty-six percent of the interest is in engineering, math and the physical sciences. An additional 12% of the interest in STEM comes from the technology majors, who are often overlooked in a discussion of STEM, yet their graduates are in great demand.

Table 2 suggests that much of the increase in interest in STEM majors is due to female students becoming more interested in the biological sciences and medicine; thus, increasing their inclination toward a STEM major as they enter college. Figure 2 shows this growing interest in STEM among female students. URMs are now as interested in the STEM majors as they enter college as majority students. (Figure 3)

As students are entering college, the same percent of URM students as non-URM students are expressing an interest in the STEM disciplines.

ASSESSMENT: DIFFERENT PREDICTORS OF ACADEMIC SUCCESS AND RETENTION FOR STEM MAJORS

To help STEM students with successful learning experiences in college, we must recognize this diversity of STEM majors and that all STEM students do not come to college with the same academic backgrounds or interests. For example, a student accepted into an engineering program probably has taken more math and physical science courses, such as chemistry and physics in high school than a student declaring an interest in a biology or pre-med program.

The predictors for academic success and retention will be different for engineering students than for non-engineering STEM students (such as biological science majors). For example, a study at a large research university showed different predictors for academic success for students in their first year of engineering than for the other STEM students. In this study, the CIRP survey variables represented pre-college characteristics. The researchers found that in predicting the first year GPA of engineering students, math and science knowledge as measured by a factor consisting of the ACT math, ACT science reasoning and placement scores were predictive of first year academic success. Compared to other research, this finding was expected. However, for the non-engineering STEM students, the overall academic preparation was more predictive of academic success than a measure of math and science knowledge. It had been expected that math and science knowledge would be a significant predictor for all STEM majors. This difference was attributed to the fact that engineering students take more math and science-based courses in the first year; thus a measure of math and science preparation was more significant than overall academic preparation (Veenstra, Dey and Herrin, 2008). This research illustrates the need to consider the diversity of STEM majors when considering a strategy for helping students succeed in their studies. This strategy needs to include the admissions criteria and student support programs for student success in the various STEM programs.

The results of this study for engineering retention are consistent with those of the Astin and Astin multi-institutional study; it provided research evidence that for engineering retention, the SAT math score, self-rating in math, aspiring to a career in engineering, high school GPA and strong orientation toward science were strong predictors for college success (Astin and Astin, 1992).

In this discussion of the differences among STEM majors, an additional study of STEM college success is worth reviewing. Ohland et al. found in their MIDFIELD study, that engineering had the highest eight-semester retention of 57% compared to non-engineering STEM of 41% and 38% for computer science majors. The MIDFIELD database includes nine public universities in the southeastern U.S. In addition, they found that engineering had few transfer students; more than 90% of the students retained in engineering after eight semesters had matriculated into engineering in their first year. In contrast, in the non-engineering STEM and computer science disciplines, more than 40% are transfers from other fields (Ohland, et al., 2008). This study is significant to the discussion because it suggests that different factors need to be considered for a retention strategy targeting engineering students compared to non-engineering STEM students. The percent of transfers into engineering is much less than for other STEM programs. The Ohland et al. study also documents that engineering has the highest eight-semester retention of 57%; other STEM majors have an eight-semester retention of less than 50%. *This further suggests that the educational processes are different between engineering and other STEM majors; thus the strategies and policies for student success may be different.*

PROVIDING A STRUCTURE FOR A STRATEGY TO PROMOTE STUDENT SUCCESS

Any strategy for student success must start with an underlying theory and an assessment. One of the most accepted theories for undergraduate student retention is Tinto's theory (Braxton, 2000), which provides a framework for assessing a college's STEM students. In any assessment of STEM students, the goal is to be data-driven, to use the data to understand the influence of the students' experiences and predict their learning needs in order for a college or university to establish a culture and student-support strategies that will help the STEM students thrive in their majors, graduate and have satisfying STEM careers.

As discussed earlier, there is a diversity of majors in the STEM disciplines, so each university will need to look at its distribution of STEM majors and decide on a rational grouping of its STEM majors. Predictors for success (and a strategy) may be different for each rational grouping. For example, the broad STEM categories defined in Table 1 could be used initially. In considering questions related to an assessment, two environments must be considered:

1) The Pre-College Environment: What were the students' experiences, attitudes, motivation, academic preparation, career goals, family support for college and extracurricular activities during high school?

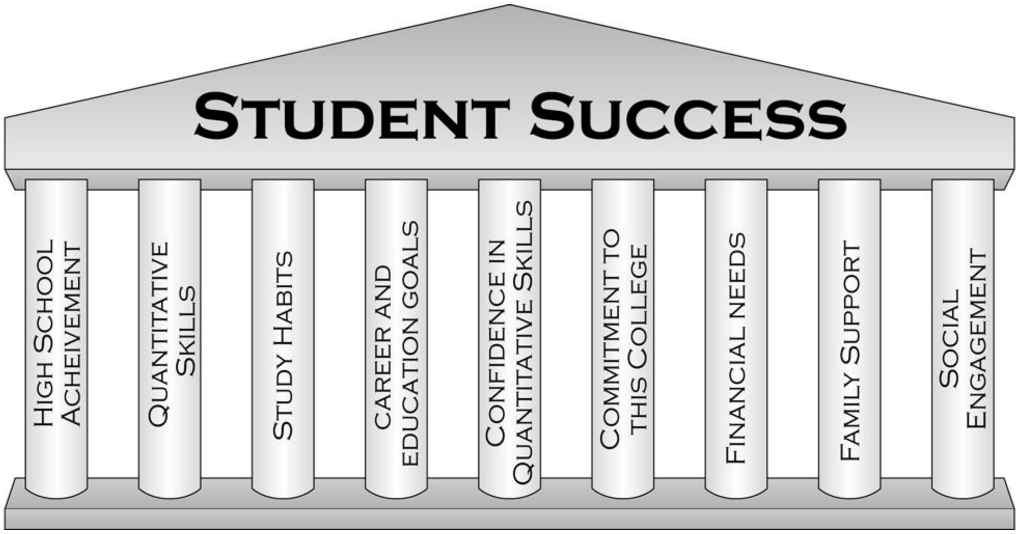
2) The College Environment: What is the college environment during the four years of college; is it engaging and welcoming; does the student make friends; is the academic environment challenging; is the student encouraged to become an independent learner; are the student's financial needs met and does the student have continuous career goals related to his/her major? Tinto described this as the academic and social integration of the student into college life. His model recognized the importance of engagement with faculty and other students in the classroom and college activities of engagement outside the classroom (Tinto, 1993, 2006).

Pre-College Environment — Characteristics That Predict Success in College

The Veenstra model provides a basis for understanding the factors related to freshman STEM retention. Based on both engineering as well as general college retention studies and Tinto's theory, nine pillars of pre-college characteristics for student success were developed. These pillars are shown and described in Figure 4.

A brief description of the model gives an overview of the Veenstra model. The research paper ("A Model for Freshman Engineering Retention" by Veenstra, Dey and Herrin) describing the model is also available. (The table in Figure 4 is adapted from this research paper.)

This model can be used for all STEM disciplines.



STEM Pre-College Characteristic	Typical Indicator	Comments
1. High School Achievement	High school GPA (grade point average) or high school rank; ACT composite or SAT total	Indicator of academic preparedness; also can indicate the ability of the student to take a full course load in college
2. Quantitative Skills	ACT math or SAT math, Placement test scores	Key knowledge of engineer is analytical skills; preparedness in this area enables student success as an engineering or physical science student
3. Study Habits	Hours/week studied in high school	Indicator of whether the student is an independent learner
4. Career and Educational Goals	Expected degree and career, self-efficacy measures	Research has shown that an early commitment to career goals significantly increases retention
5. Confidence in Quantitative Skills	Self-rating of confidence in math, science and computers (survey)	Research has shown that confidence is a key factor in student success
6. Commitment to Enrolled College	Choice of college, reason for choosing this college, satisfaction with choosing this college	In general college education research, significant for retention
7. Financial Needs	Amount of loans, percent of financial needs that are not met	Research indicates that financial needs may influence the type of college. Financial needs typically do not affect first year retention, but can significantly affect probability of college graduation.
8. Family Support	Educational level of parents, income level of parents	Major contributing factor to student success
9. Social Engagement	Social involvement; connectedness with teachers and other students	Significant in general college retention studies

Figure 4: Nine Pillars for Student Success
(Adapted from Veenstra (2008) and Veenstra, Dey and Herrin, (2009))

In Figure 4, Quantitative skills and confidence in quantitative skills were specific to the engineering retention studies; these two pillars would also be expected to be significant for STEM majors such as physics. High school achievement was significant both for engineering and general college retention studies and would be expected to be significant for all STEM majors. The table in Figure 4 gives examples of variables that would describe each pillar for student success. The UCLA/HERI CIRP survey variables provide a database of possible variables. See Veenstra, Dey and Herrin (2008) for a suggested list of CIRP variables for each pillar and a validation of this model using the nine pillars for student success.

Once a rational grouping of the STEM majors is determined, an assessment of pre-college characteristics that contribute to either the college GPA or retention can be evaluated.

The College Environment

Measures of student engagement, commitment to a major or career, overall confidence, self-efficacy, study habits and academic performance have been used as predictors of adjustment to the college environment and its influence on student academic success and retention. Additionally, institutional factors such as the size of the college, selectivity and availability of financial aid have been considered in studies of student retention.

Furthermore, college activities that promote participation in the STEM disciplines have potential for encouraging students to continue in a STEM major. Survey courses on STEM careers, extracurricular activities such as a solar car competition, and internships all help. Retention is very much a multi-dimensional issue, requiring multiple approaches for retention.

A number of assessment studies on the college environment have been conducted and are available in the higher education journals. Many of these assessments are based on Tinto's theory. An excellent reference is Braxton's *Reworking the Student Departure Puzzle*.

ASSESSMENT LEADS TO AN IMPROVED STRATEGY FOR STUDENT RETENTION

An assessment is only effective and adds value if it is used to "feedback" an improved strategy for student success. From its assessment, a college will develop a deeper understanding of the incoming characteristics of the students. Not all the pillars for student success in Figure 4 will be significant factors for all STEM majors at all colleges. Significance will depend on the mission of the college or university and the STEM field. After the assessment results are known, a strategy around the nine pillars of student success can be developed. The admissions process or student support activities may need to be adjusted.

One approach proposed by Veenstra (2009) was to develop a measurable metric for each of the nine pillars for student success and for each student, to evaluate his/her preparation based on these metrics. If a student has a low (weak) score for any of the student success pillars, learning processes that would aid the student would be discussed with the student (such as tutoring or mentoring) early in the first semester of college. Those pillars that were shown to be the most significant in a college's assessment would have the highest priority.

From the assessment, the faculty could refine its strategy for student success. The assessment may indicate that some freshman courses need to be revised. More activities to engage students in the learning process may be needed. Seminars on internships and STEM careers may benefit some students. This is especially the case if students are unsure of their choice of major.

Hopefully, the refinement of a strategy for student success shows increased student retention, but sometimes, due to multiple actions taken, it is difficult to completely identify the reason for the improvement. With the availability of multivariate statistical approaches to assessment, a systematic approach to understanding the assessment can often be accomplished.

After the assessment and appropriate student support activities are implemented, it is important to conduct a second assessment to understand whether a change in the educational processes (for example, a new course or activity) was successful in improving student academic success and retention.

An assessment is only effective and adds value if it is used to "feedback" an improved strategy for student success.

SUMMARY

A review of possible STEM majors showed the diversity of majors that STEM includes. The UCLA/HERI publications on the CIRP survey were used to review freshman interest in the STEM disciplines. Although engineering is often mentioned when STEM majors are discussed, the breadth of the majors varies from the biological sciences to the physical sciences and engineering.

With the discussion in this paper, it can be concluded that entering college freshmen are becoming more interested in pursuing a STEM major. No doubt, part of this interest is due to the increased national focus on STEM education and the opportunity for well-paying and rewarding STEM careers. The overall interest in a STEM major has increased 20% in the past 20 years--from a 32% interest in a STEM college major in 1990 to a 39% interest in the fall of 2009 (using reports on the CIRP survey). With the need for more doctors and medical professionals, the increased interest in the biological sciences and medical professional majors to over 50% of the STEM field is reassuring. However, despite the efforts by the engineering education community, interest in engineering has not increased and represents only one-fourth of the overall interest in the STEM fields.

From 1990 to 2009, interest in the STEM majors among female students entering college has also increased. The percent of probable STEM majors among female students has increased by 35% to 36% in 2009 and is close to the 43% interest in the STEM majors among male students. Most of this increase is in the biological sciences and medical professions; interest in engineering is about the same today as in 1990. The major concern continues to be that women are not attracted to engineering in higher percentages; only about 4% of all female students seeking a bachelor's degree indicated a probable major of engineering as they enter college. There is good news about interest in STEM by minority students. Under-represented minorities have the same level of interest in the STEM majors as majority students (34%).

Recent research as discussed in this paper indicates that predictors for student success will vary depending on the STEM major and especially for engineering majors. This has implications of different strategies and policies for STEM student success for both the admissions process and the design of student support programs. To improve the graduation rates of STEM students, we need more effective strategies based on our assessments of entering students. Using the Veenstra model, an approach was discussed for assessments of STEM students. We need to use these assessments in a timely manner to develop and refine strategies for student success that will engage more students in the STEM disciplines.

Finally, we need to incorporate these assessments and strategies into a continuous improvement cycle that leads to a more effective learning process for each freshman class, which then will lead to a higher STEM graduation rate and more satisfied graduates!

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Dr. Cindy P. Veenstra is director of Veenstra and Associates, and consults with colleges on STEM retention issues. Cindy earned the Ph.D. in Industrial and Operations Engineering at the University of Michigan applying the fields of quality engineering and statistical thinking to engineering student retention and general college student retention. She also holds a Master's degree in statistics and believes that surveys are powerful tools for identifying strategies for student success. Her research studies systemic approaches for improving the educational processes and college graduation rates of all STEM students.

Dr. Veenstra has published her research in the *Journal for Engineering Education*, the leading journal in the field of engineering education, *Advances in Engineering Education*, the *Annals for Research in Engineering Education*, *The Journal for Quality and Participation* and the *ASQ Higher Education Brief*. Her research articles are available at the Veenstra and Associates website.

She is an ASQ Fellow and chair-elect of the ASQ Education Division. She is an associate editor of the Quality Approaches in Higher Education, a peer-reviewed journal published by the ASQ Education Division. She is also advising editor for the *ASQ Higher Education Brief* which includes an annual special issue on k12 outreach STEM education. She serves on the board of the ASEE College-Industry Partnerships Division. She has substantial engineering experience at engineering companies; her experiences at Motorola influenced her approaches to engineering education systems thinking.

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