Empowering Learning in Engineering: A Study of Learning Styles, Strategies, and Success of First-Year Students

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ABSTRACT: *We have been engaged in a large-scale study funded by the National Science Foundation (U.S.) that seeks to understand the relationships between college engineering students' ways of learning and their success in a traditional first-year engineering curriculum. A research team has investigated the learning preferences and study habits of approximately 1,000 first-year engineering students at a large, research-oriented, public university in the United States. A battery of learning style inventories, surveys and questionnaires, and weekly journal-like responses to focused questions provides the basis for correlations between these dimensions of students' experience, their academic success as measured in grade point average, and retention. Focus-group interviews with randomly selected participants have provided qualitative exploration of the statistical results. The results of the study have pointed to specific, identifiable groups of students who are at risk within the engineering curriculum as it is currently structured. These students stand out not because of any intellectual failures but because certain aspects of their learning styles and behaviors are not conducive to the instructional methods and paradigms to which they are exposed. Not surprisingly, the study also confirmed that the quality of the employed study habits impacts the success of students in general but also within each learning style.*

By using these results to describe the matches and mismatches among students' styles and strategies, the content of courses, and instructors' teaching styles and strategies, we are developing a taxonomy to help students select a particular strategy for the mastery of different types of information and teaching techniques. In this phase of the project, the objective is to increase the students' awareness of their own learning while simultaneously increasing the number of learning strategies they have at their disposal. So armed, the students should be able to improve the effectiveness and efficiency of their learning, modifying their individual strengths and preferences to overcome the inherent mismatches between learning and teaching styles that are prevalent in undergraduate engineering education.

1 INTRODUCTION: CAUSE FOR CONCERN

The low retention rate of students in engineering is well known. Research in the United States, for example, shows that only 43% of students who enter engineering programs finish their degree in an engineering field [1], yet demand for qualified engineers continues to grow [2]. Some students decide that engineering is not a career they wish to pursue; others enter alternative programs because they are unable to learn effectively in their engineering curriculum. Because many engineering programs also have high standards for admission, the reasons for these failures are not easily explained by low ability among entering students. Something else appears to be responsible for the widespread disillusionment of those engineering students who change the course of their studies or are unable to complete their engineering degrees successfully.

Intrigued by this problem, the authors embarked on a multi-year study of the factors that lead to the success and retention of engineering students and those factors that might explain why many students are not successful and/or choose to pursue other areas of academic inquiry. The study seeks to explore the relationships among students' learning styles, study strategies, attitudes, and success in the first year of their engineering programs. The analysis of these relationships, while ongoing, has already pointed to critical factors associated with--and predictive of--student success, including both extrinsic factors such as study habits and intrinsic factors such as the learning style or "disposition" the student brings to the engineering program and, indeed, to all of their academic work.

2 DESCRIPTION OF THE STUDY

The study described here, funded by the National Science Foundation (U.S.), is a multi-pronged analysis of data gathered from approximately 1,000 entering (first-year) engineering students at North Carolina State University, a large, comprehensive, publicly-funded university located in Raleigh, North Carolina. These students started their college careers in mid-August of 2002. In the context of a one-credit introduction to engineering, data were gathered from students using the following instruments:

Pittsburgh Freshman Engineering Attitudes Survey (PFEAS): This extensively tested instrument consists of 50 multiple-choice questions, in thirteen areas, that explore incoming engineering students' attitudes toward engineering as well as aspects of learning [3, 4, 5, 6, 7]. In a typical item, a student might be asked to rate how strongly he or she agrees with a particular statement, such as a reason for studying engineering.

Learning and Study Skills Inventory (LASSI): This instrument gathers information about the study habits and practices of students using an 80-item survey. Students judge how well certain statements apply to them. The survey elicits information on ten scales: Attitude, Motivation, Time Management, Anxiety, Concentration, Information Processing, Selecting Main Ideas, Study Aids, Self Testing, and Test Strategies [8, 9]. On the Anxiety scale, for example, an item might include the statement, "When I am studying, worrying about doing poorly in a course interferes with my concentration."

Learning Type Measure (LTM): The LTM is based on the work of learning theorists, particularly Kolb (see Fig. 1) [10]. A questionnaire consisting of 26 items "measures individual preferences for selecting, organizing, prioritizing and representing knowledge, information and experience" [11]. For example, students decide whether they learn best collectively or alone, or whether they have difficulty with instructors who follow rules or who are emotional.

The LTM assigns the learner to one of four categories; tendencies can also be strong or weak depending on overlap with other categories. Type 1, "why" learners ("divergers") prefer listening and discussing ideas, and learn best by relating new ideas to prior knowledge and personal experiences. They are comfortable in situations that allow them to use language strategies to connect people to ideas. They thrive in environments where there is respect for everyone's ideas and where divergent thinking, opinion generating, and subjective interpretations are encouraged [12].

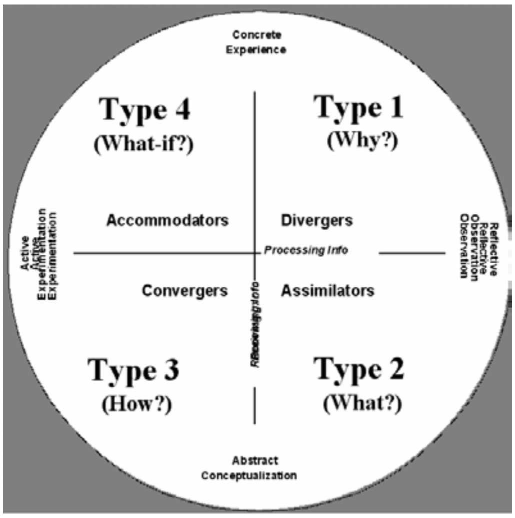

Figure 1 – Model of Kolb's Learning Styles

Type 2, "what" learners ("assimilators") have a preference for critiquing information and collective objective data that support their ideas. They learn best by assimilating abstract facts into coherent theories, preferring to form judgments based on verifiable data. They are most comfortable in situations that allow them to use their "tough mindedness" to deduce correct and precise answers.

Type 3, “how” learners (“convergers”) prefer experimenting and testing ideas. They learn best by using “down-to-earth” problem-solving strategies to make sense of ideas. They like to work with concrete, real-life circumstances, and to test whether something is workable. They do best in contexts that privilege individuality and experimentation. They also excel at tasks that require straightforward, objective thinking resulting in a measurable product.

Type 4, “what-if” learners (“accommodators”) prefer original thinking and trial-and-error problem-solving. They learn best by looking for patterns and relationships that connect their personal experience to new information. They are comfortable when exploring multiple applications of ideas, and enjoy creativity and originality. They know how to generate stimulating and thought-provoking discussions that have social significance. They do best in environments where there is a convergence of ideas and a respect for the unconventional.

Surveys and journals: Weekly electronic surveys were used to determine students’ attitudes toward their academic and social experiences on campus. Students rated the strength of their agreement with statements such as “I am able to figure out for myself how to learn new information and material.” In addition, a choice of three open-ended questions allowed the students to write journal entries describing their feelings and concerns more freely--e.g., “Describe the instructional setting (large lectures, small groups, labs) with which you experience the most frustration.” To gauge possible changes in students’ beliefs and knowledge, surveys were repeated during the second half of the academic semester, and students wrote on open-ended questions they had not chosen during the first administration of the surveys. Resulting data include approximately 27,000 responses of 50-200 words.

Personal interviews: At the end of the first year of study, randomly-selected students representing different LTMs were interviewed to explore the preliminary results in greater detail.

Preexisting data for correlational analysis: In addition to data gathered from various instruments and surveys administered to the students as part of the study, some data on the student cohort were readily available from the admissions and other records at the University for correlational analysis: demographic information such as gender and ethnicity, grades in high school, and, as the study proceeded, grades in specific courses and grade point averages (GPAs) at the end of each semester.

Analysis of quantitative data was correlational, statistically relating various measures using ANOVA, regression, and factor analysis. Journal responses were analyzed using linguistic text-mining software in order to discern any lexical and other patterns correlating with other data.

3 RESULTS

Because of the large quantities of data gathered in this study, an attempt to provide a comprehensive summary would be fruitless in the context of these proceedings. Instead, we have chosen to include here the most significant results given the central aims of the research study.

1. First-Year Engineering students have minimal learning strategies. Overall, the first-year engineering students in the cohort did not enter the University with many productive learning strategies. The LASSI subscales are scored on a scale from 0-100, with 0-50 suggesting that the students need help in this area. From the Cohort of 2002, it was found that 7 of the 10 scales had a mean of less than 50 for the cohort as a whole. Among the lowest and highest were the following:

    - The Attitude Scale, which assesses students’ attitudes and interest in college and academic success, was the lowest of all measures (Mean: 31).
    - The second lowest result came from the Self-Testing Scale, which assesses students’ use of reviewing and comprehension monitoring techniques (Mean: 38).
    - Another significantly low result was the Time-Management Scale, which assesses academic and non-academic scheduling (Mean: 38).
    - The highest score came from the Selecting Main Ideas Scale, which assesses student ability to select main ideas for critical topics and details (Mean: 53).

    Given the generally poor strategies students brought to their academic learning, personal interviews of selected students in their *second* year of study probed this factor. In these interviews, students:

- generally described their freshmen year as a positive experience, and were generally happy about their academic experiences at NC State and within College of Engineering;
- believed that their high school experience provided them with a strong academic foundation, but *not* the necessary learning strategies needed to be successful in college;
- indicated that the availability of professors outside of the classroom is a highly desirable and positive factor that influences their ability to learn the material and to be successful;
- reported that they take advantage of resources on campus to help them be more successful (Supplementary Instruction Session, Teaching Assistant office hours, etc.);
- strongly recommended that incoming freshmen get to know their professors outside of class by going to the professors during office hours for assistance or by going to tutorial sessions offered by the professors;
- indicate that they are more motivated *now* (in their second year) as a student based on their experiences from their first year at NC State;
- overwhelmingly recommend that first-year students in the College of Engineering get involved with other students in classes, upperclassmen, etc. as a strategy that would help them be more successful;
- report considerable informal, self-motivated "networking" themselves to survive academically.

2. <u>Success is defined in part by learning style</u>. Because thus far our study has tracked the cohort through only one full year of engineering, one definition of "success" used by the authors is the student's ability to continue in the College of Engineering along the prescribed curriculum which requires a minimum GPA and a C- or better in specific courses. (Students can gain admission into an engineering degree program by completing two courses in chemistry, an introductory engineering course, four semester hours of English composition, two semester of mathematics and one course in physics, with a "C –" or higher, and introductory computer course with a satisfactory (S). Students who have completed the above courses, and achieved a total grade point average of 2.9 within the first 60 credit hours of enrolment at NC State, are granted admission to one of 17 engineering degree program of their choice.)

Results for the entire cohort show that first-year engineering students with a low GPA (less than 2.5 on a 4 point scale) also had a low high school GPA (less than 4.1 out of a 5 point scale). These students also had a low motivation scale score on the LASSI (mean of 27) and less than average confidence in basics sciences (chemistry, physics, calculus, engineering) as measured by the PFSEAS survey given at the end of the first semester.

At this point such an observation would confirm traditional predictors of success (prior performance and test results in areas relating to Engineering fields). However, results of the LTM paint a more complex picture. Comparisons were made between the students' LTM scores and their first year cumulative GPA at NCSU. We predicted that LTM type 2 and 3 learners would do well in traditional settings of large lecture classes, while LTM's 1 and 4 would struggle. As Fig. 2 indicates, this prediction was confirmed by the analyzed data. Because of the high correlation between the SAT and GPA, the data analysis included a covariance of the first year engineering students' GPA by the SAT (the main college-entrance examination used across the U.S. as a standard for admission) Mathematics subtest, and then grouped the students by their highest LTM score.

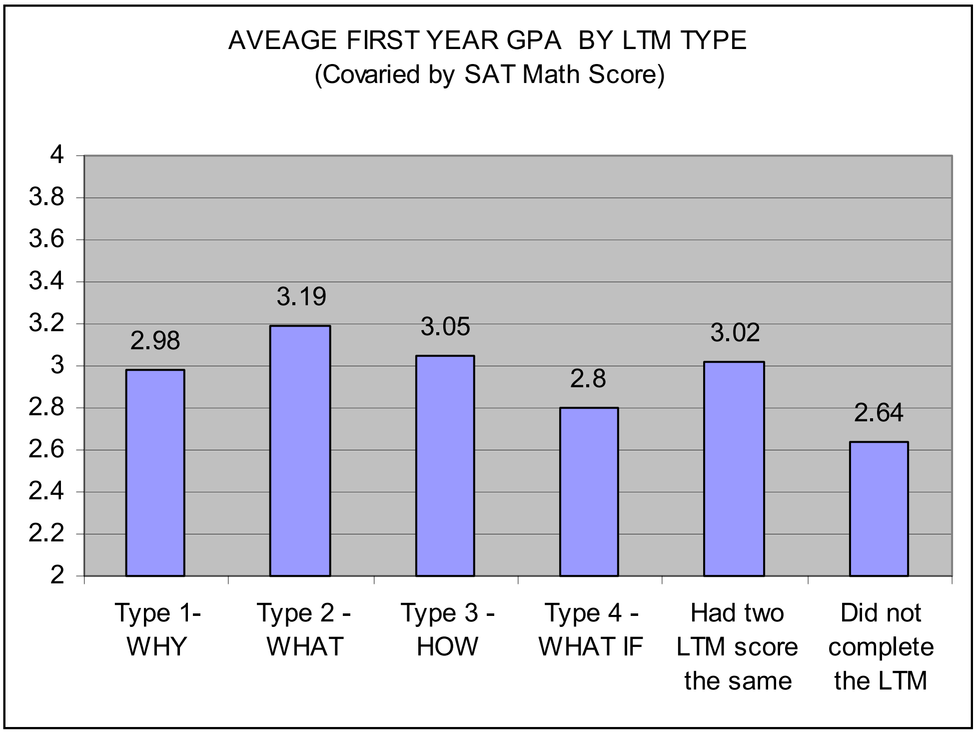

Figure 2 – Average First Year GPA by Learning Type

3. Several Factors Predict First year Grade Point Average (GPA). The first year GPA was used for other statistical analyses as well. One thrust was to identify the strongest predictors of GPA from a set of background data available for new students such as learning preferences or attitudes that they brought to the institution. While some data had been generated through the admissions process (High School GPA, SAT scores), more information was collected using standardized survey questionnaires (LTM, LASSI, PFEAS) and the above mentioned weekly journals. Regardless of what statistical methods were used (correlations, multiple regression, etc.) the following variables showed the strongest correlation with the first year GPA:
   - **High School GPA** : The higher the high school GPA, the higher the first year GPA.
   - **SAT Math Score**: The higher the SAT math score, the higher the first year GPA.
   - **Ethnicity:** Those from African American or Native American ethnicity tended toward lower first year GPA.
   - **LASSI Motivation** Scale: The higher the Motivation Scale (higher motivation, diligence and self-discipline), the higher the first year GPA.
   - **LASSI TMT** Scale: The more and better time management skills, the higher the first year GPA.
   - **PFEAS "Study"**: The higher the confidence in study habits, the higher the first year GPA.
   - **Journal** Question "Alone": Students who answered that they **usually prefer** to study alone showed a higher GPA.
   - **Journal** Question "Prepare": Students who answered that they **usually wonder** if they are prepared for university academics tended toward a lower GPA.
   - **Journal** Question "Habits": Students who answered that they **usually feel** grades and study efforts are related tended toward a lower GPA.

When the cohort of students was divided into two main subgroups according to their first year GPA (High GPA= GPA > 3, Low GPA = GPA < 2.5), a more detailed set of comparative evaluations was made. As Fig. 3 indicates, there is a relationship between HIGH and LOW GPA, LTM type, and four of the LASSI subscales: Time Management (TMT), Motivation (MOT), Attitude to study (ATT), Self-Testing (TST). For example, if the student is an LTM 4 and had a low first-year GPA, the student also had, on average, a low time management score and low motivation score on the LASSI survey. If a student belonged to the LTM 1 group and had a GPA below a 2.5, the student also had, on average, lower scores in time management, motivation, self-testing, and attitude.

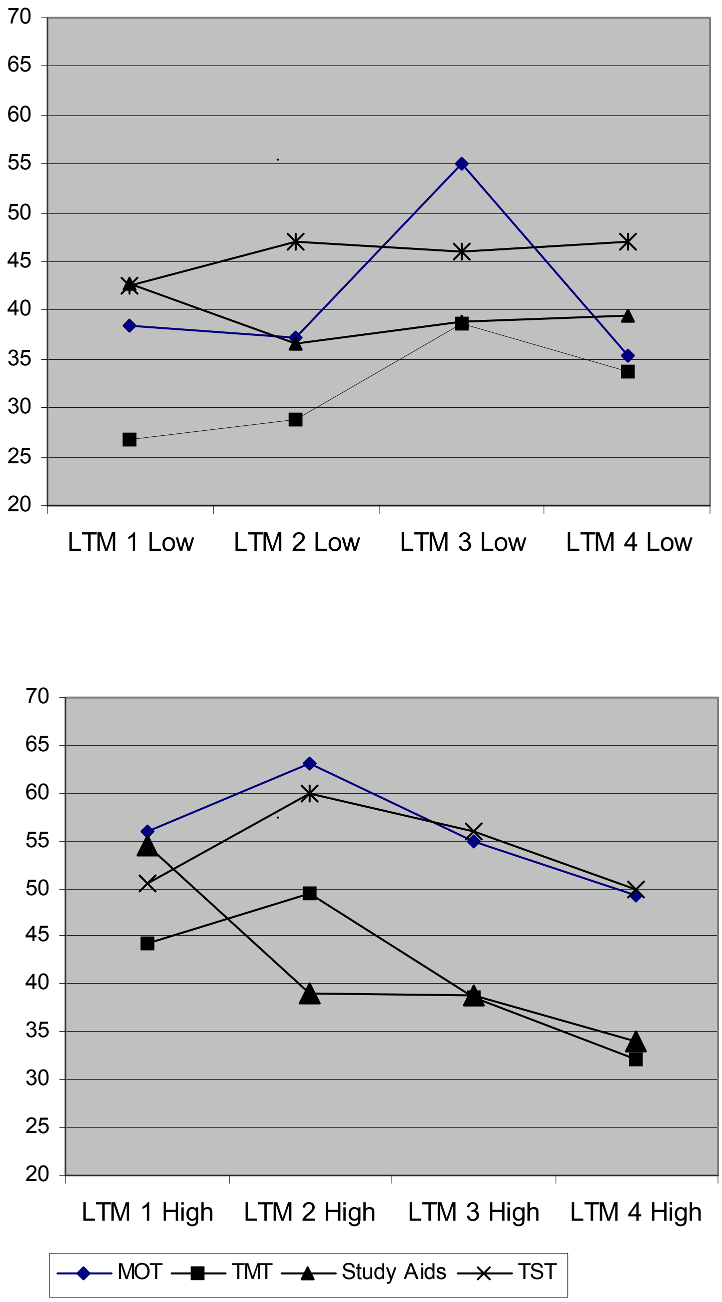

Figure 3 – Comparison of High GPA and Low GPA Students With LTM and LASSI Scores

4. Results vary by gender and ethnicity. Fig. 4 presents a comparative distribution of the preferred learning styles according to gender and ethnicity. Underrepresented Minorities (URM) are students of African American, Native American or Hispanic ethnicity.

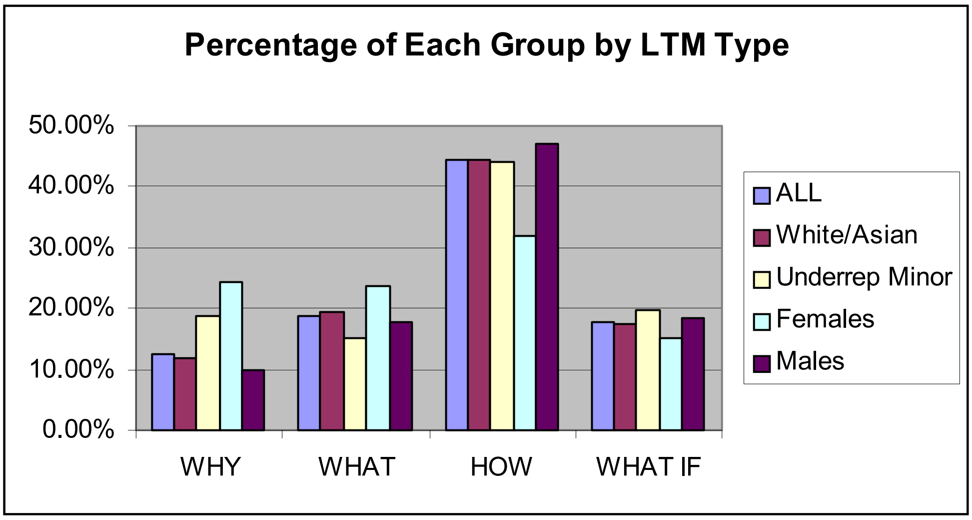

Figure 4 – Learning Type Preferences by Gender and Ethnicity

It is interesting to note that more females belong to LTM 1 – WHY category than males, and more underrepresented minorities are LTM 1 than White/Asian students while the various subgroups are evenly distributed in LTM 4 – WHAT IF category. As noted above, the LASSI subscales of Motivation (MOT) and Time Management (TMT) are good predictors of GPA. As shown in Table 1, females have statistically significant higher scores on these scales than do the males. Overall the females score higher than the males on 8 out of the 10 LASSI scales with the highest scale being Motivation (MOT) and the lowest Attitude (ATT). There were no significant differences in underrepresented minorities as compared to White/Asian students on the LASSI sub-scores.

Table 1. Comparison of LASSI Motivation (MOT) and Time Management (TMT) Scores by Gender and Ethnicity

	MOT	TMT	First Year GPA
Female	57*	41*	3.27*
Males	45*	34*	2.89*
Underrepresented Minority	42	32	2.80*
White/Asian	48	36	2.97*

*significance at p<.05

It can also be seen that female students achieve higher GPAs than males. Interestingly, Figure 5 and Figure 6 show that the same trends hold for every LTM type. The question remains, if females do better in their courses and have higher attitude scores, why do they still have a lower persistence rate in engineering?

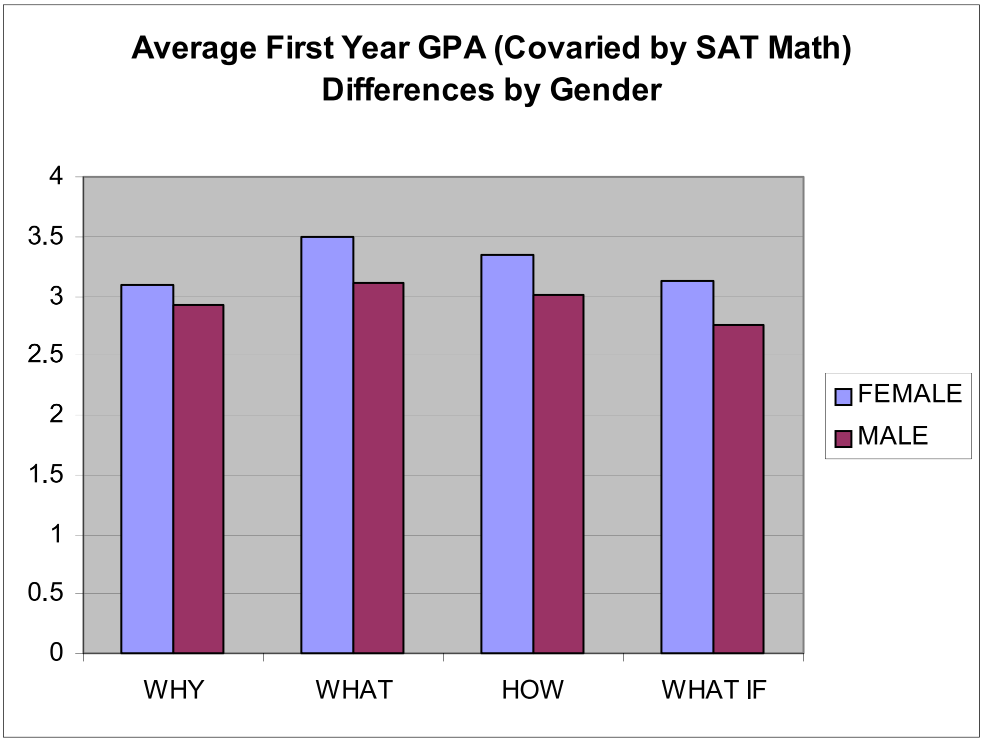

Figure 5 – Average First Year GPA by Learning Type and Gender (Covaried by SAT Math Score)

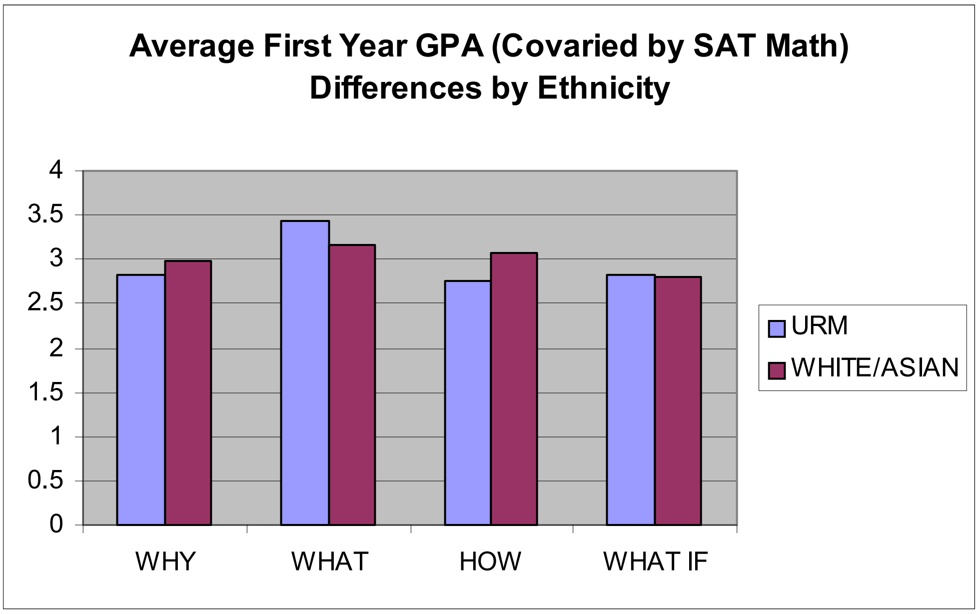

Figure 6 – Average First Year GPA by Learning Type and Ethnicity (Covaried by SAT Math Score)

4 CONCLUSIONS

To date, our analysis of data gathered from a cohort of over 1,000 first-year engineering students suggests areas of concern—and potential reform—both generally across the entire cohort and within specific, identifiable groups. Overall, the students come to the University lacking crucial learning strategies for success, particularly time-management skills. They are generally weak in their attitudes and interest in college and academic success, compounding their inability to schedule and monitor their time appropriately to ensure the timely completion of academic tasks. At this early stage, they do not appear to be intrinsically motivated to engage in the engineering field, a problem potentially linked to the lack of extrinsic motivating features of their curriculum. Higher motivation, diligence, and self-discipline all appear to be linked to success, based on correlations with students' performance in the first year.

Students belonging to the LTM Type 1 and Type 4 groups are, by definition, more inclined toward creative thinking and active learning, yet the results of the study show that they are also at higher risk than students who belong to LTM Type 2 and 3. Discussions with practicing engineers suggest a high desirability for the kinds of thinking common among Type 1 and 4 learners. One implication of this paradox concerns the basic (entry-level) curriculum in engineering, which tends toward a more abstract, lecture-filled, and rote-based model antithetical to the learning styles of LTM types 1 and 4. The first year, then, would appear to be a curricular space in need of considerable scrutiny and enhancement, perhaps through the integration of more student-centered, team-based, active, and project-oriented coursework common in the advanced stages of various engineering tracks.

Our analyses also show that predicting success requires a complex matrix of variables, including intrinsic factors such as students' perceptions, prior training in study habits, and styles of thinking and learning, and extrinsic factors such as the availability of mentors and faculty, tutorial programs, peer-organized social and study groups, and, perhaps most crucially, the kind of instructional paradigms and methods common in the curriculum. Our continuing research will (1) explore this matrix in greater detail through qualitative analysis (interviews) and through a test of the predictability of the success formula on the 2004 entering cohort, and (2) begin testing specific interventions, such as mentor programs and instruction in study skills to determine the most effective method of ensuring that students thrive in their programs and go on to become successful engineers.

ACKNOWLEDGEMENTS

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