2006-1812: WHAT AFFECTS STUDENT SELF-EFFICACY IN AN HONORS FIRST-YEAR ENGINEERING COURSE?

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What Affects Student Self-Efficacy in an Honors First-Year Engineering Course?

Abstract

Self-efficacy, an individual's belief in his or her ability to perform certain tasks, has been linked to student achievement, interest, and retention in the fields of science, engineering, and mathematics. The more positive a student's self-efficacy, the better the student will perform in class and in other aspects of his or her life. Helping engineering students develop their sense of self-efficacy requires an understanding of what influences students' efficacy beliefs and how students form their beliefs. Previously, we identified nine factors affecting the efficacy beliefs of first-year engineering students enrolled in *Engineering Problem Solving and Computer Tools* at Purdue University: understanding or mastery of the material; drive or motivation toward success; teaming issues; computer skills relevant to the material; the availability of help and ability to access it; issues surrounding the attempt and completion of assignments; student problem-solving abilities; enjoyment, interest, and satisfaction associated with the course and its material; and grades related to aspects of the course. Some factors promoted students' efficacy; others reduced it. A parallel study has been conducted with first-year honors engineering students at the same university. A survey was administered as a required homework assignment to students in the first-year engineering class, *Honors Engineering Problem Solving and Computer Tools*. Students were asked to rate their confidence in their ability to succeed in the course as well as to list and rank the factors they perceived as influencing their self-efficacy beliefs. This paper will present the influences of honors first-year engineering student self-efficacy beliefs and compare them to the beliefs and influences of non-honors first-year engineering students. Such information may help educators construct a learning environment that promotes positive self-efficacy, and thus the achievement and retention of their first-year engineering students.

Introduction

Self-efficacy—an individual's belief in his or her ability to perform certain tasks[1]—can affect one's overall effort, persistence in overcoming obstacles, and the choices he or she makes in either a positive or negative manner. Studies of undergraduate students in science, technology, engineering, and mathematics (STEM) fields have linked their persistence[2-9], achievement[2,3,10,11], and interest[2,10-13] in their disciplines to their self-efficacy beliefs. For example, many women who leave STEM programs have less confidence in their abilities than those who stay in the programs ("stayers"), despite earning similar grades[8,14,15]. Moreover, female stayers possess lower self-efficacy perceptions than their male colleagues[16-18].

Studies of STEM students have revealed factors that influence students' self-efficacy. In one such study, a total of nine factors were identified as influencing the efficacy beliefs of more than 20% of the engineering students in a first-year engineering course[19]: understanding or mastery of the material; drive or motivation toward success; teaming issues; computer skills relevant to the material; the availability of help and ability to access it; issues surrounding the attempt and completion of assignments; student problem-solving abilities; enjoyment, interest, and satisfaction associated with the course; and course grades.

These nine factors (with the possible exception of drive or motivation) support Bandura's theorized four sources of self-efficacy[1]. Often the strongest influence, *mastery experiences* consist of the interpretation of individual performance on specific tasks. According to Bandura, a positive interpretation increases self-efficacy while a negative interpretation decreases self-efficacy. *Vicarious experiences* occur when an individual's efficacy is affected by his or her perception of others' achievements while performing similar tasks. These experiences are particularly influential when individuals perform tasks of which they have little or no experience in that particular area. Bandura's third identifiable factor, *physiological states*, describes the effect of stress, anxiety, fatigue, and other emotions that an individual may encounter when performing specific tasks. Finally, the verbal judgments of others, *social persuasions* according to Bandura, may also play a role in shaping an individual's self-efficacy.

Promoting positive efficacy beliefs among engineering students requires understanding how students arrive at their efficacy beliefs. While a few qualitative studies of self-efficacy belief formation have been conducted[19-21], none to our knowledge (either qualitative or quantitative) have focused on honors students at the postsecondary level. This study is designed to answer the questions: Which aspects of an honors engineering course for first-year engineering students influence student self-efficacy beliefs, and how do these aspects vary by gender? Responding to an open-ended question incorporated in a Likert-scale questionnaire, first-year students enrolled in an engineering honors program discussed factors they found particularly influential. Those factors most frequently cited as affecting students' beliefs are described in detail and compared to those cited by first-year engineering students at the same university not participating in the honors program.

Research Design

Theoretical Framework

This research focuses on the different ways individuals understand and perceive phenomena in the world; therefore, a phenomenographical framework has been adopted. More detailed descriptions of phenomenography may be found in the work of Marton et al[22].

Participants

Participants for this study consisted of 192 students enrolled in ENGR 116, *Honors Engineering Problem Solving and Computer Tools*, at Purdue University in Fall 2004. This course teaches fundamentals such as problem-solving, computer logic and tools (including UNIX, Excel, and MATLAB), teaming, economics, statistics, and mechanics principles in engineering contexts to students enrolled in the engineering honors program. Eligibility requirements for the honors program include SAT or ACT scores of at least 1360 or 61, respectively, and a high school class rank of within the top 10% (or a university-calculated high school GPA of 3.8 or higher should no class rank be available). Engineering students in the honors program are required to take seven credits of honors designated courses in their first year, of which ENGR116 is highly encouraged. National Merit finalists are also eligible to take part in the course.

Of the 38 women and 154 men enrolled in ENGR 116, 26 women and 67 men responded to the survey, an overall response rate of 48%. The respondents were 94% (n=87) Caucasian American, 5% (n=6) Asian American, 1% (n=1) International, and 1% (n=1) did not list an ethnicity. The composition of the entire ENGR 116 course was 89% Caucasian American, 6% Asian American, 2% Hispanic American, 1 % Native American, 0.5% International, and 1% did not list an ethnicity. Surveys from one female student and four male students were eliminated from the analysis due to ambiguity in the factors discussed. Four additional male survey responses were removed from the ranking analysis due to ambiguities in their rankings, which left 59 male surveys to be analyzed. Comparisons of SAT/ACT scores and final ENGR 116 course grades revealed no differences between the scores of the respondents and the scores of students in the ENGR 116 course overall. Similarly, the SAT/ACT scores and final ENGR 116 grades earned by male and female respondents were representative of the SAT/ACT scores and final course grades earned by men and women in the entire ENGR 116 course.

Instrument, Procedure, & Analysis

A survey was administered in ENGR 116 early enough in the fall semester that students' final grades could not be determined but late enough that students were familiar with the learning environment. Moreover, students were informed that their survey responses were completely confidential and would not be linked back to their individual identities.

Following the survey Likert-scale item, "Rank the extent to which you agree with the statement, 'I am confident I can succeed in ENGR 116'", students were told to "think about the factors you considered in the previous question. Describe briefly all of the factors on which you based your confidence rating to this particular question. Write everything that comes to mind." Hence, an open-ended question was used to enable students to discuss factors influencing their personal self-efficacy for course success. Students were given the option to list up to 10 separate factors and then encouraged to go back and rank each factor 1 through 10 according to the level of influence (1= most influential and 10= least influential).

An identical survey was administered to non-honors engineering students in ENGR 106, *Engineering Problem Solving and Computer Tools*. A detailed description of the instrument and research procedures is given in Hutchison et al[19].

Responses were gathered and coded independently by two researchers using the program ATLAS.ti, version 5.0. Codes were written for every response given by the students. These codes were then grouped together in categories according to central themes (i.e. grades, understanding of material, problem solving abilities, etc). Factors that students ranked as most influencing their self-efficacy were also coded as such. In many instances, students listed more than one factor belonging to a single category (e.g., "My exam grades," "My homework grades," and "My quiz scores"). Because analysis was based on the percentage of students citing each factor, such cases were only counted once in the corresponding category (i.e., the student was counted once in the category of *Grades*). Conversely, instances also arose in which one student response fit more than one category (e.g., "I can usually finish the homework assignments, even though it takes me a long time to understand them."). In these cases, the student was counted in all applicable categories (i.e. the student's response was counted once both in *Working* Assignments and *Understanding/Learning*). Researcher agreement measured 86%; factors not initially agreed upon were discussed until agreement was reached. Z-tests ($\alpha = 0.05$) were performed to determine statistically significant gender differences and differences between the honors and non-honors data.

Results and Discussion

Upon analysis of student responses, thirteen categories of factors cited as efficacy-influencing by at least 20% of the men or women in the sample were identified. Categories include understanding and mastery of material; drive or motivation toward success; teaming issues; computer skills relevant to the material; the availability of help and ability to access it; issues surrounding the attempt and completion of assignments; prior experience; student problem-solving abilities; enjoyment, interest, and satisfaction associated with the course and its material; grades related to aspects of the course; comparison among classmates; course exams; and class projects (Fig 1).

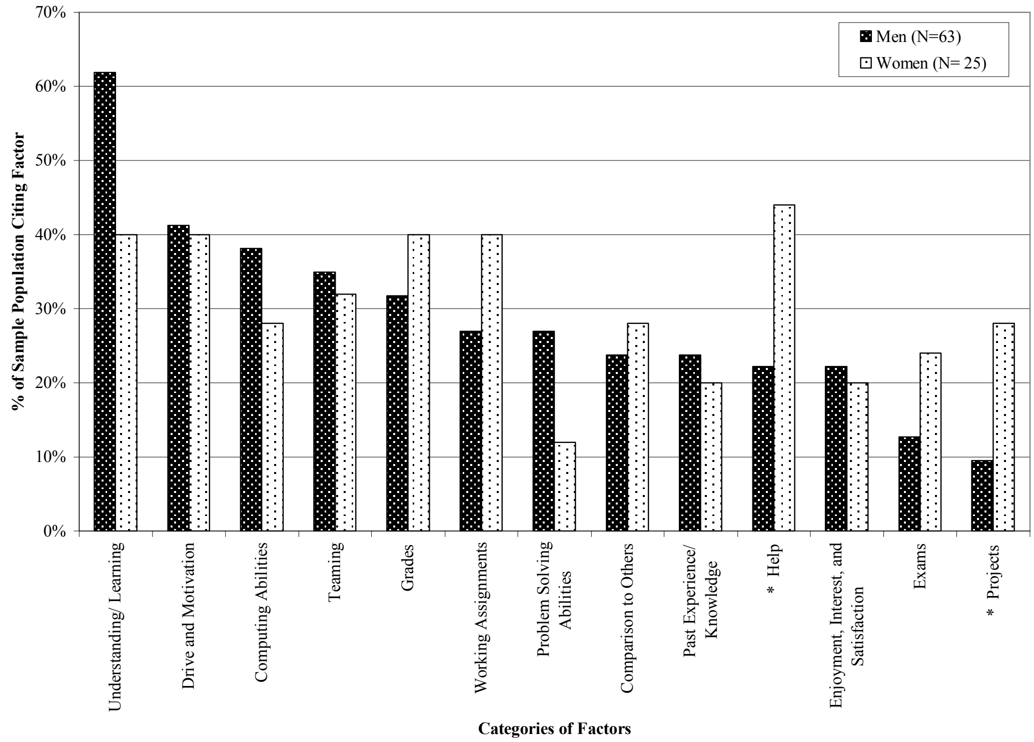

*Figure 1. Factors indicated by at least twenty percent of male or female honors engineering students as influencing efficacy beliefs (*p < 0.05).*

Nine of these factors were cited as efficacy-influencing by first-year engineering students in the non-honors version of ENGR 116 (i.e. ENGR 106)[19]. At least 20% of the honors students also discussed four additional factors: comparison to others, projects as a subcategory of *Working Assignments*, exams, and previous experience or knowledge. Descriptions of the factors, as voiced by the honors students, are given below.

Understanding/ Learning: Affecting a significant fraction of men and women, understanding/ learning was listed by 61.9% male and 40% female respondents. Student responses included in this category reflected a student's ability to comprehend and learn general material such as concepts being taught in class, the homework assignments, labs, and projects. A student's expression of difficulty or ease of understanding certain material being presented was also placed in this category. Student responses included "I am learning the material.", "I understand a majority of the concepts in ENGR 116.", or "I do have trouble understanding the very difficult problems."

Drive and Motivation: Responses concerning an individual's ability to accomplish personal tasks such as passing the class, persistence to understand or work out problems, and determination to either do or not do well in the class were placed in this category. Students also gave responses regarding their motivation and desire, as well as their ability to work hard in the course. Nearly 40% of both men and women listed this factor. This indicates that for the honors engineering course, roughly the same fraction of men and women think about drive and motivation when considering factors that influence their self-efficacy beliefs.

Computing Abilities: One focus of the honors engineering course is to familiarize students with engineering programs such as UNIX, MATLAB, and EXCEL. Student responses in this category concerned students' ability to use and understand these engineering programs, e.g. "My ability to use MATLAB to solve lab task problems". It was found that 38.1% men and 28% women gave responses under this category. Some students explicitly stated their computer abilities were negatively correlated to their self-efficacy ("My insecurity using MATLAB and EXCEL").

Teaming: Working in teams in the freshmen honors engineering course is a required part of the curriculum and a factor influencing students' self-efficacy beliefs. Responses such as "My teamwork skills are important." and "I feel that the teams are slightly unfair for projects and therefore ours end up about average because we work hard. However, none of us have had experience with anything we have done, while other teams have members that have participated in competitions." suggest that teaming abilities can have a negative impact on self-efficacy for some and be beneficial for others. A total of 32% of the women surveyed stated that teaming played an important role in shaping their self-efficacy while 34.9% of the men gave such responses.

Grades: Many students gave responses concerning the type of grade they were getting in the class, a final grade they were striving for ("…succeeding in 116 means earning an A"), grades received on exams and homework assignments, and issues concerning the grading policy ("… not enough weight is given to projects"). It is important to note that this category does not contain the response "Passing the class." since students did not specifically state what grade they were striving for in order to pass the class. Therefore, that response is placed in the *Drive and Motivation* category. Responses in this category contained quotations such as "My previous exam score." and "Grades so far." Of the men and women surveyed, 31.8% and 40%, respectively, listed responses in this category.

Working Assignments: Working assignments influenced 40% of the women and 27% of the men sampled. This category describes a student's ability to attempt or complete course homework and laboratory assignments, excluding assigned projects. (Note: a response explicitly referring to a student's understanding of an assignment, e.g. "I understand the homework", was categorized as *Understanding/ Learning* since the student did not discuss actively working the homework.) When asked what influenced their efficacy beliefs, student responses included: "Completing the lab tasks", "Ability to do CHIP homework [timed online homework program where students submit their answers on a weekly or biweekly basis]", "I do the work", or "I do well on the homework". These responses suggest students' self-efficacy beliefs to be boosted when they are able to successfully work or complete assignments or other tasks given to them. In other instances, working assignments had a negative effect on one's efficacy (i.e. "With the way the CHIP system is set up, if you let one problem go too long, there's no way you'll be able to get caught up.").

Problem Solving Abilities: Of responses concerning a student's ability to think logically and solve problems on assignments and problems given in lab, 27% of men and 12% of women suggested that this factor was influential in shaping their self-efficacy. Students made comments such as "I can solve the mathematical problems given to me" and "Ability to solve the problems given." Furthermore, comments reflecting a student's understanding of problem solving techniques were also included in this category since he or she stated specifically what was being understood (e.g. "I understand the engineering problem solving method.").

Comparison to Others: Students' efficacy beliefs were also influenced by the comparisons that they made with fellow classmates concerning performance at a level at or above average (i.e. grades), previous engineering knowledge (such as math, physics, or programming knowledge), or abilities to understand course concepts fall into this new category. Both men and women (23.8% and 28%, respectively) stated that they compare themselves to their peers in one way or another. Responses included "Test score comparison to average.", "When listening to how well other students think they do, I compare myself to them.", and "I know I have better scores than other kids."

Past Experience/ Knowledge: While the honors engineering course did not require pre-requisite courses, students still felt that their background, particularly high school background, influenced their self-efficacy in either a positive or negative way. The response "There are certain aspects of Calculus and Physics that I am expected to know, yet have never been taught in high school courses." describes how a student's background has had a negative effect on his efficacy beliefs. Those with prior experience were affected positively by this factor. Approximately 23.8% men and 20% women cited this factor as influencing their self-efficacy.

Help: A student's ability to seek and gain help from peers, teaching assistants, and the course professor describes this category. Responses pertaining to students not seeking help when they should have or not knowing where to receive help were also placed within this category. Students discussed both positive and negative aspects that they associated with seeking help from their instructors. Others expressed that the fact they were able to seek help when it was needed was a boost to their efficacy. The difference in the fractions of women (44%) and men (22%) citing help as a factor influencing efficacy approached statistical significance ($z = -2.04$, $p = 0.0411$).

Enjoyment, Interest, and Satisfaction: Students who gave responses such as "Lack of interest in the material.", "I enjoy the projects.", or "I enjoy engineering." described their fulfillment in the course and/or the major. Only 22.2% of the men and 20% of the women surveyed, stated that this factor influenced their self-efficacy beliefs.

Exams: The exams category consists of students' feelings (such as frustration, improvement, satisfaction) regarding exams, not the exact grade of the exam. For example, some students gave the response "I felt I did very well on the last test." What the student meant by "well" cannot be determined from the response (i.e. it could reflect a possible score or the student's ability to perform); nevertheless, this particular element of the course affects self-efficacy beliefs. Among women, 24% gave responses that were included in this category, while only 12.7% men listed the factor as influencing their self-efficacy.

Projects: In the honors engineering course, projects assigned to students comprised 30% of the aggregate grade. Many students gave responses regarding their ability to do and complete assigned projects. A greater proportion of women (28%) than men (9.5%) listed this factor ($z = -2.20$, $p < 0.05$).

Rankings

Of the factors listed by students, drive and motivation, grades, and understanding were listed by students as influencing their self-efficacy beliefs the most (i.e. ranked #1 amongst the students) as shown in Figure 2.

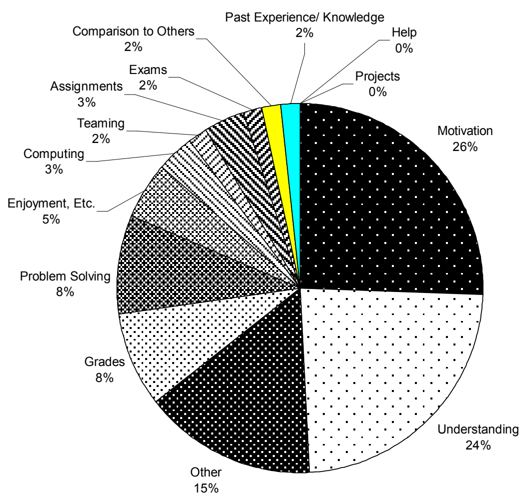

Figure 2a. Percentage of male sample population ranking each factor #1 (most influential).

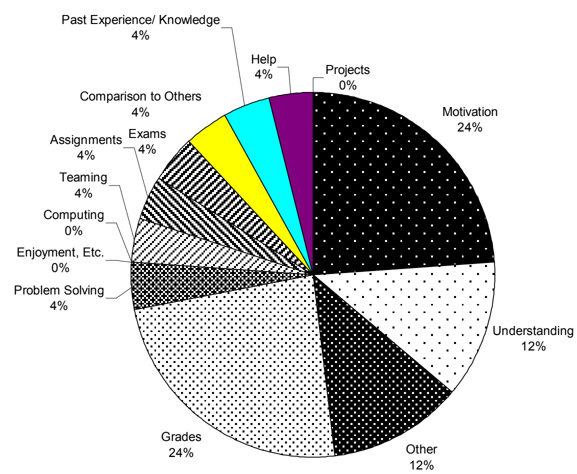

Figure 2b. Percentage of female sample population ranking each factor #1 (most influential).

As seen in Figure 2, 26% of men viewed drive and motivation as the most influential factor affecting their engineering efficacy; and 24% of the men viewed understanding/ learning as being the most influential factor. While 24% of the women viewed drive and motivation as most influential, an equal fraction (24%) also considered grades to be most significant. In contrast, only 8% of the men considered grades to be of such importance. Twelve percent of the women described understanding as most influencing their self-efficacy. These identified differences in the factors cited as most influential by men and women were not, however, statistically significant.

Comparisons with Responses in Non-Honors Course (ENGR 106)

Many of these results parallel findings obtained from students in ENGR 106, the non-honors class alternative to ENGR 116[19]. All of the factors cited by ENGR 106 students as influencing their self-efficacy were also cited by students in ENGR 116. Four additional factors (comparison to others, projects -which originally was part of *Working Assignments* in the non-honors data-, exams, and previous experience or knowledge) also emerged in the honors engineering student data. While these factors were cited by students in both ENGR 106 and ENGR 116, these factors were cited by a greater proportion of ENGR 116 students (i.e. > 20%). It is possible that honors students frequently consider a wider variety of mastery experiences (e.g. completing projects, performance on an exam) or vicarious experiences (e.g. how their prior knowledge compares with that of their peers) when assessing their ability to succeed in their engineering class. It is also possible that the students are more willing or better able to explicitly articulate the factors they perceived as influential. Whether this is indicative of more-developed metacognitive skills, as suggested in the gifted education literature, can not be determined.

In both ENGR 116 and ENGR 106 (see Table 1), male and female students ranked their drive and motivation, more than any other factor, as the factor most influencing their engineering self-efficacy.

*Table 1. Factors influencing engineering self-efficacy of honors and non-honors[19] students (**p<0.05).*

	Honors Students (ENGR 116)				Non-Honors Students (ENGR 106)			
	Men		**Women**		**Men**		**Women**	
	% Citing Factor	% Citing Factor as Most Influential (#1)	% Citing Factor	% Citing Factor as Most Influential (#1)	% Citing Factor	% Citing Factor as Most Influential (#1)	% Citing Factor	% Citing Factor as Most Influential (#1)
Understanding / Learning	62%	**24%**	**40%	**12%**	55%	**18%**	**72%	**17%**
Drive and Motivation	41%	**26%**	40%	**24%**	43%	**18%**	51%	**24%**
Computing Abilities	38%	**3%**	28%	**0%**	41%	**10%**	38%	**9%**
Teaming	35%	**2%**	32%	**4%**	42%	**3%**	51%	**2%**
Grades	32%	**8%**	**40%	**24%**	21%	**5%**	**18%	**6%**
Assignments	27%	**3%**	40%	**4%**	32%	**6%**	34%	**8%**
Problem Solving Abilities	27%	**8%**	12%	**4%**	25%	**5%**	24%	**5%**
Comparison to Others	24%	**2%**	28%	**4%**	0%	**0%**	0%	**0%**
Past Experience/ Knowledge	24%	**2%**	20%	**4%**	0%	**0%**	0%	**0%**
Help	22%	**0%**	44%	**4%**	19%	**1%**	38%	**2%**
Enjoyment, Etc.	22%	**5%**	20%	**0%**	25%	**4%**	26%	**7%**
Exams	13%	**2%**	24%	**4%**	0%	**0%**	0%	**0%**
Projects	10%	**0%**	28%	**0%**	0%	**0%**	0%	**0%**

In ENGR 106, *Understanding/ Learning* was the next most common factor ranked as #1 (approximately 18% of male and female ENGR 106 students ranked *Understanding/*

Learning as #1). While almost a quarter of male honors students also ranked *Understanding/ Learning* as most influential, one-quarter of the female honors students ranked *Grades* as most influential (12% of female honors students listed *Understanding/ Learning* as #1). These differences were not found to be statistically significant.

Differences were also identified in the percentages of ENGR 106 and ENGR 116 students citing several of the factors. The percentage of non-honors women listing *Understanding/ Learning* as an influential factor is significantly higher (denoted as ** in Table 1) than that of honors women (72% of non-honors women versus 40% of honors women; $z = -3.13$, $p < 0.05$). Similarly, the percentage of honors women listing grades (40% versus 18% of non-honors women) is significantly higher than that of non-honors women ($z = 2.53$, $p < 0.05$). No statistically significant differences were observed between the responses of males in ENGR 106 and males in ENGR 116. Explanations of these findings may include differences in class formats or student/instructor goal orientations. For example, a higher minimum GPA is required in the honors program than in the non-honors program, thus placing more of an emphasis on grades in the honors setting. A qualitative investigation (e.g. interviews with subsequent phenomenographic analysis) will provide insights regarding how first-year honors engineering students interpret their experiences when assessing their engineering efficacy, and therefore will help clarify these findings.

Implications for Instructors

While differences exist in the efficacy-influencing factors cited by men and women and honors and non-honors students, drive and motivation remains highly important across all groups. Thus, motivational issues may be a significant factor to consider in the attempt to promote the development of positive efficacy beliefs in students and, therefore, potentially improve student retention in STEM programs. Many students' responses suggested that they were self-motivators; however, instructors should develop their courses such that specific measures are included to assist in the continuous enhancement of motivation. A study spanning seven years and including more than 700 students, has shown eight components repeatedly cited by students as highly motivating: instructor enthusiasm, demonstrated relevance through examples, instructor organization, appropriateness of difficulty level, active student participation, variety of instructional methods, instructor interest in students and their learning, and the use of real, concrete examples[23]. Alternatively, McKeachie suggests guiding students toward developing specific learning goals for a given course and requiring that they track their progress toward these goals as a means of motivation[24]. By remaining mindful of these relatively straightforward ways in which students may be motivated, instructors can be better equipped to promote positive efficacy.

Conclusions

Both first-year engineering students enrolled in an honors program and those not enrolled in the honors program cite the same factors as affecting their ability to succeed in their first engineering course: understanding and mastery of material; drive or motivation toward success; teaming issues; computer skills relevant to the material; the availability of help and ability to access it; issues surrounding the attempt and completion of assignments; student problem-solving abilities; enjoyment, interest, and satisfaction associated with the course and its material; and grades related to aspects of the course. A significant fraction of students in the honors course also describe prior experience; comparisons among classmates; course exams; and class projects as influencing their engineering self-efficacy. Of all of these factors, motivation and understanding were most often ranked as the factor most influencing the self-efficacy beliefs of male first-year engineering students (honors and non-honors programs) and female first-year engineering students (non-honors program). Motivation and grades were most often ranked as the most influential factor by female engineering students in the honors program. These results provide a first attempt at understanding what first-year engineering students enrolled in an honors program consider when assessing their self-efficacy beliefs. More work is required, however, to better understand the means by which the students form their efficacy beliefs (i.e. how they interpret and weight these factors when forming their beliefs). Through such work, aspects of the learning environment that affect student self-efficacy can be identified and interventions developed to promote student self-efficacy, and thus achievement and persistence, in the field of engineering.

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