CAREER: Student Motivation and Learning in Engineering

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Abstract

This study seeks to identify factors that contribute to students' motivation to pursue engineering, and to correlate these motivational attributes to problem-solving and knowledge transfer. Understanding these relationships will address one of the greatest challenges facing engineering educators: preparing students for a future of complex problem solving in the face of rapid technological change and globalization. The study population is drawn from bioengineering (BioE) and mechanical engineering (ME), thus allowing comparisons between two disciplines that have similar content and skill sets but different student demographics and career goals.

Quantitative methods were applied to explore differences in motivation for students in different majors in the initial phase of the study. Results showed subtle differences between student motivations in different majors, and indicated the need to explore motivation factors more deeply through mixed methods. Data from a survey on student motivation and problem solving self-efficacy and two interviews (one related to motivation and the other to their problem-solving approaches) were analyzed. The motivation interviews revealed differences in students' perceived future possible selves, which affect their perceptions of the relevance of present activities. Ongoing problem solving interview data analysis will further reveal how motivation differences affect students' actual problem solving practices.

Introduction

While academic performance is the most common metric used to gauge student success, it is not an all-encompassing representation of the learning experience. Student motivation feeds cognitive processes, such as the drive to master technical concepts, the desire to apply them, innovate, create, solve, and synthesize.[1-3] In other words, motivation is a major factor in the development of metacognitive and solving problem skills. A key factor in student motivation is their perceptions of their future possible selves, which are also linked to cognition and perceptions of themselves in the present.[4-5] This research seeks to help educators understand factors that contribute to students' motivation, such as expectations, values, and goals, as well as their cognition and academic performance. Understanding these relationships will address the challenges facing engineering educators: increasing interest in engineering, creating a more diverse engineering workforce, and preparing students for a future of rapid technological change and globalization.

The major goals of this project are to answer four specific research questions:
- RQ1: What factors contribute to students' motivation to pursue engineering?
- RQ2: How do motivational attributes correlate to learning and cognition in engineering, especially problem-solving and knowledge transfer?
- RQ3: How do motivational attributes change over time as knowledge, experience and skills in one's field develop?
- RQ4: What relationship, if any, do the particular aspects of bioengineering (BioE) and mechanical engineering (ME) have to motivation, learning and cognition in those disciplines? How do these relationships compare between the two disciplines?

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Methods

The factors contributing to students' motivation to pursue engineering were explored through quantitative methods. A motivation survey (Motivation and Attitudes in Engineering, or MAE) was developed and tested on a population of first year engineering students at a southern land grant institution.[6] The differences in motivation factors for students in different majors and the motivational differences between students pursuing different long-term goals (individual majors, majors grouped by popularity, and majors grouped as "traditional" or "interdisciplinary"). Binomial linear regression analysis was used to investigate the relationship between self-reported motivations and long-term goal (declared major). Possible predictors for the model were factor scores from the MAE survey, with the outcome variable as declared majors. From these analyses, we examined how student motivation predicts long-term goals (major selection).

The correlations between motivational attributes and learning and cognition in engineering, especially problem-solving and knowledge transfer, were initially examined by combining quantitative results with problem-solving data from a previous study.[7] MAE survey responses were correlated with specific problem solving practices, strategies and errors identified in problems solved in a first year engineering course for a subset of the students who completed the survey. This portion of the study is being continued as a mixed methods study, with quantitative results being further explored through interview questions that probe why and how students solve problems (Table 1). A phenomenological approach is being used to create rich descriptions of student experiences with the interactions between future-oriented motivations and present tasks.

Changes in motivational attributes over time are being examined through a longitudinal study, following selected participants at the end of each year in their major. Analysis of the data is ongoing, and results will be reported on this phase of the research in a subsequent report.

Relationships between the particular aspects of BioE and ME with motivation, learning and cognition in those disciplines, and how those relationships compare between the two disciplines are being examined through a study of the attributes of motivation and problem solving self-efficacy for BioE and ME students. Data includes quantitative analysis of previously collected MAE survey data and additional survey data from BioE and ME students enrolled in a second-year course in their majors.

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Table 1. Questions for semi-structured interviews. Questions in italics were used if needed to prompt students for further explanations of their responses.

Long Term Goals and Motivation
What are your goals for the future? (*Possible follow-up questions: What are your personal goals for the future? What are your career goals for the future? Describe where you see yourself in 10 years.*)
What would you ideally like to be in the future? (*Possible follow-up question: If you could pick one thing and it could happen what would it be)?*
What do you think you can be in the future? (*Possible follow-up questions: What are you actively striving for? What goals are you currently pursuing to reach this future?*)
What do you not want to be in the future? In other words, what jobs, or careers do you know you do not want to pursue?
Why are you pursuing an engineering degree?
How long do you plan on remaining in an engineering related profession after graduation? (*Possible follow-up question: How long after graduation do you plan on using technical information as part of your day to day work?*)
What parts of your education do you see as relevant to your future? (*Possible follow-up questions: What skills are relevant to ideal self (who you would ideally like to be)? What skills are relevant to who you think you could be? What parts of your education do you see as not relevant to your future?*)
What skills do you view as important for your profession?
How did you develop these conceptions of your future?
Short-Term Tasks/Goals
What is an engineering problem? *(Possible follow-up questions: What is an engineering problem in your classes? If you were to write a problem, what would you want an engineering problem to look like?)*
Describe an engineering problem that would be beneficial to you in your engineering education. *(Possible follow-up questions: What features of this problem make it an ideal problem? Examples: well-defined versus ill-defined, single versus multiple answers)*
Have you encountered any of these problems while pursuing your degree? If yes, please describe in what context and what it looked like. If no, please describe where your ideal problem could fit into your degree.
Why do you solve engineering problems?
What types of problems do you solve in your non-engineering classes? Why do you solve these problems? Do you approach, solve, or work on these problems any differently than your engineering problems, and if so, how?
What if anything do you hope to get from solving engineering problems?
How important are grades? *(Possible follow-up question: Why are grades important to you?)*
Interconnection of Long- and Short-Term Motivation
How do the problems you solve relate to your future goals: in engineering courses? In co-op/intern/research experiences?
How do your future goals affect how you approach the problems you solve?
How do you future goals affect your actions with respect to your courses?
What do you do when you fail achieving your goal in engineering? *(Possible follow-up questions: How would you describe failure? What do when you struggle to get to an answer?)*
How do you define success? *(Possible follow-up question: What do you consider success for a task?)*

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Key Outcomes

The study on differences in motivation for students in different majors showed that the survey instruments used detected differences between grouped engineering majors on individual items, but they do not elucidate motivation differences between students' long-term goal of engineering major.[8] Interdisciplinary majors report more struggles in their introductory courses, valuing their introductory courses more, feeling that they are working harder, and expecting a better grade from their introductory courses when compared to students in traditional majors. Interdisciplinary students value the benefits of a major with possible scholarship money and the opportunity to benefit society, while traditional majors think engineers do interesting work and enjoy designing and building things. These results are mirrored when comparing students in BIOE, an interdisciplinary major, to those in Top Enrollment majors and Low Representation majors (with less than 15% female enrollment), largely but not exclusively traditional majors. BIOE's are less likely to consider switching majors than both comparison groups. BIOE females feel their grade has a lower impact on their future, and have more confidence in their choice of major than females in low representation majors. Compared to top enrollment majors, BIOE's feel they are struggling more with their courses and have less faculty support. BIOE females feel they have a greater understanding and ethical responsibility, and confidence in their choice of major compared to top enrollment females. Due to the consistency of these results a predictive model of choice of long-term engineering goal was created. Students who score highly on knowing an engineer as a reason for selecting a major, wanting a good potential salary, designing and building things, and their perceptions of the present were likely to be traditional engineers. Students who want to prove themselves in the hardest possible major and benefit society are likely to be in interdisciplinary majors.

Correlations between long-term motivation factors and problem solving processes included students' solution to the three introductory engineering problems. These problems had different features; for example, one was more open-ended in nature; one was more of a rule-applying type of problem, and one was more of an exercise in applying physical principals to an engineering context).[9] For this reason, inconsistent patterns of performance were observed between them, resulting in varying correlations across all three problems.[10] This can be credited to several factors. First, the students' motivation attributes were assessed at the beginning of the semester, and the problems were given over the course of a semester. Prior MAE survey results showed that at least one of the motivation factors (expectancy) significantly changes over the course of an academic year. It is possible that correlations exist but were not detected between student motivation and the time at which they completed the problems and their problem solving performance or outcomes. Variations in student motivation may also be occurring on the task level and may not be related to their long-term goals.[11] The depth and variability of students' cognitive and metacognitive processes are limited for first year engineering problems. First year students are either not likely to demonstrate higher level cognitive process, which may be correlated to motivation, within the problems included in this analysis or may not have the experience to actually use these processes. MAE survey included three attributes of motivation (expectancy, perceptions of the future and perceptions of the present) that were significant predictors of student persistence in engineering. These factors do not adequately encompass the many factors that contribute to student motivation, or the varying levels of motivation that students possess.[12]

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Through the study of BioE and ME student motivation and problem-solving self-efficacy, a factor analysis revealed that the MAE survey is valid for use with upper-level students with a few minor modifications (deletion of items that did not load into the factors of Perceptions of the Present, Perceptions of the Future, and Expectancy). Cronbach's α's for this study are all within the good to excellent ranges, indicating internal consistency of the items. Problem solving self-efficacy loaded as a separate, single factor, indicating that students view it separately from long-term goals, and view problem solving as one step or hurdle instead of a series of subcomponents. Given students' prior experiences with problem solving they may be chunking the steps of solving a problem together.[13-14] Results have indicated differences between majors on several motivation factors. Students' with higher GPA had significantly higher expectancies and problem-solving self-efficacy. No significant differences were seen based on major, sex, race, or math scores; this may indicate that students who make it to major specific courses have similar motivation profiles. BIOE's have significantly higher expectancies (5.28) than ME's (4.83). ME's have a statistically lower GPA (3.31) than BIOE's (3.51, p=0.03). Differences in GPA between BIOE's and ME's may explain higher expectancy for BIOE's.

Discussion, Conclusions and Future Work

Results of the study of characteristics of student motivation are guiding our current qualitative study of motivation of engineering students related to long-term goals. These results have prompted our research team to explore the application of different theoretical frameworks beyond Expectancy-Value theory, upon which the MAE survey was initially designed. These include identity[15], possible selves[5], and goal orientation[16]. A population of participants has been purposefully selected to participate in a series of interviews about motivation to pursue engineering as an educational and career goal. Additionally, the results of this study only explored motivation to long-term goals, and do not speak to task level or motivation toward short-term goals. The qualitative study will include interview questions related to task specific motivations toward the short-term goal of problem solving.

While the results of the study of correlations between motivation and problem solving processes revealed few significant results, the analysis is directing our explorations of the connection between these two domains. One approach currently under way is having students solve a more complex and open-ended problem to produce more variability in student responses. Open ended problems designed to introduce new contexts force students to transfer knowledge gained in previous learning environments to new situations.[17-20] In particular, Bransford and Schwartz's preparation for future learning model for transfer is concerned with how and what students transfer, which is relevant to this study.[17] We are employing teaching interviews as a means for collecting qualitative data about students' problem solving processes.[20] Students are prompted to think about new information that they may not have previously considered. Interviews are coded by examining students' use of "source tools" (resources that students bring with them to solve the problem), "target tools" (attributes of the situation that students identify as relevant), and "work bench" (processes that connect new information learned and previous experience or knowledge). Our work shows that identification of specific target tools (identifying unknowns) is correlated to students' perceptions of the future. Because open ended problems often prove too difficult for first year engineering students, we are including upper-level engineering students (sophomores, juniors and seniors) who have more training and skills to solve problems designed to elucidate knowledge transfer. Upper-level engineering students have also begun to pursue

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specific courses within their majors that can develop their possible selves.[5] Engineering is often a poorly defined major for incoming students due to a lack of experience with the field prior to college.[21] Improved understanding of what an engineer is and does may allow students to form more defined possible selves. The better definition allows students to form balanced possible selves of what they want to become and what they want to avoid becoming.[22-24] The creation of this balance is similar to extended future perspective described by Husman and Lens.[4] Both balanced possible selves and extended future perspectives have been shown to increase student success at attaining their future goals, and overcoming the hurdles they may face. Oyserman has shown that students who have well developed possible selves are more likely to take action related to pursuing college.[25] These differences in student perceptions of the future leading to differences in action may appear in students' problem solving processes, including knowledge transfer.

Our study of BioE and ME student motivation and problem-solving self-efficacy shows that there are in fact differences in students' motivation related to long- and short-term goals. However, our results to date include a relatively limited set of motivational factors that can drive students to perform. Our ongoing studies include additional frameworks to describe the motivation of students pursuing engineering degrees and solving engineering problems as described above. The types of problems and different features of the problem solving process as viewed by students cannot be clearly understood from this data, as indicated by the single problem solving self-efficacy factor. Understanding the types of problems and problem features that students acknowledge as relevant, and the correlations between these problem features and the students' motivation profiles are the focus of our current research through multiple interviews with second-year engineering students. These methods include teaching interviews, in which students solve problems and are subsequently prompted by an instructor (interviewer) to walk through their solutions, explaining their thought processes and working through any stopping points or questions.

Acknowledgement

References

1. Dweck C.S. & Leggett E.L. (1988) A social-cognitive approach to motivation and personality. Psychological Review [Internet]. Psychology Press. 95(2):256–73.

2. Crawley F.E. & Kobala Jr. TR. (1994) Attitude research in science education: Contemporary models and methods. Science Education [Internet]. 78(1):35–55.

3. Pintrich P.R. (2000) Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. Journal of Educational Psychology [Internet]. American Psychological Association. 92(3):544–55.

4. Husman J. & Lens W. (1999) The role of the future in student motivation. Educational Psychologist. Taylor & Francis. 34(2):113–25.

5. Markus H. & Nurius P. (1986) Possible selves. American Psychologist, 41(9), 954–969. doi:10.1037//0003-066X.41.9.954

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6. Kirn A., Morkos B. & Benson L. (2012) Work in Progress: How Differences in Student Motivation Characterize Differences between Engineering Disciplines. ASEE/IEEE Frontiers in Education Conference. Seattle, WA.

7. Grigg S. J. & Benson. L. C. (2012) Effects of Student Strategies on Successful Problem Solving. 2012 ASEE Annual Conference, San Antonio, TX.

8. Benson, L. and A. Kirn (2013) CAREER: Student Motivation and Learning in Engineering. ASEE 2013 Annual Conference. Atlanta, GA.

9. Jonassen D.H. (2004) Learning to Solve Problems. San Francisco, CA: Pfeiffer.

10. Kirn, A., S. Grigg and L. Benson. (2013) Relationships between Engineering Student Motivation and Problem Solving Performance. American Educational Research Association Conference. San Francisco, CA.

11. Bandura, A. (1977) Self-efficacy: toward a unifying theory of behavioral change. Psychological review, 84(2), 191.

12. DeShon, R. P., & Gillespie, J. Z. (2005) A motivated action theory account of goal orientation. The Journal of applied psychology, 90(6), 1096–127. doi:10.1037/0021-9010.90.6.1096

13. Chi, M., Feltovich, P., & Glaser, R. (1981) Categorization and representation of physics problems by experts and novices. Cognitive science, 5, 121–152.

14. Donovan, M., Bransford, J., & Pellegrino, J. (1999) How People Learn. Retrieved March (p. 374). National Academy of Sciences.

15. Hazari, Z., Potvin, G., Tai, R. H., & Almarode, J. (2010) For the love of learning science: Connecting learning orientation and career productivity in physics and chemistry. Physical Review Special Topics - Physics Education Research, 6(1), 1–9.

16. Pintrich, P. R. (1999). The role of motivation in promoting and sustaining self-regulated learning. International Journal of Educational Research, 31(6), 459–470.

17. Bransford, J., & Schwartz, D. (1999). Rethinking transfer: A simple proposal with multiple implications. Review of research in education, 24, 61–100.

18. Lobato, J. (2003). How Design Experiments Can Inform a Rethinking of Transfer and Vice Versa How Transfer Has Been Addressed in Early. Educational Researcher, 32(1), 17–20.

19. Lobato, J. (2006). Alternative perspectives on the transfer of learning: History, issues, and challenges for future research. The Journal of the Learning Sciences, 15(4), 431–449.

20. Rebello, N., Zollman, D., Allbaugh, A., Engelhardt, P., Gray, K., Hrepic, Z., & Itza-Ortiz, S. F. (2004). Dynamic transfer: A perspective from physics education research. In J. P. Mestre (Ed.), Transfer of Learning from a Modern Multidisciplinary Perspective. Information Age Publishing.

21. Katehi, L., & Pearson, G. (2009). Engineering in K-12 Education. Washington D.C.

22. Oyserman, D., Brickman, D., & Rhodes, M. (2007). School Success, Possible Selves, and Parent School Involvement. Family Relations, 56(December), 479–489.

23. Pizzolato, J. E. (2006). Achieving college student possible selves: navigating the space between commitment and achievement of long-term identity goals. Cultural diversity & ethnic minority psychology, 12(1), 57–69.

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24. Pizzolato, J. E. (2007). Impossible Selves Investigating Students' Persistence Decisions When Their Career-Possible Selves Border on Impossible. Journal of Career Development, 33(3), 201–223.

25. Oyserman, D. (2004). Possible selves as roadmaps. Journal of Research in Personality, 38(2), 130–149.