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CAREER: Student Motivation and Learning in Engineering

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Dr. Beshoy Morkos is a newly appointed assistant professor in Mechanical and Aerospace Engineering at the Florida Institute of Technology. Dr. Morkos was a postdoctoral researcher in the Department of Engineering and Science Education at Clemson University performing NSF-funded research on engineering student motivation and its effects on persistence and the use of advanced technology in engineering classroom environments. Dr. Morkos received his Ph.D. from Clemson University in the Clemson Engineering Design and Applications Research (CEDAR) lab under Dr. Joshua Summers. While at Clemson, he received many national awards and was a recipient of the ASME Graduate Teaching Fellowship. His research focuses on developing computational representation and reasoning support for the management complex system design, and is currently implemented in multiple industry practices. Dr. Morkos' research has been published in several journals and conference proceedings around the world. He graduated with his B.S. and M.S in Mechanical Engineering in 2006 and 2008 from Clemson University and has worked on multiple sponsored projects funded by partners such as NASA, Michelin, and BMW. His past work experience include working at the BMW Information Technology Research Center (ITRC) as a research associate, and for Robert Bosch Corporation as a manufacturing engineer. Dr. Morkos' research thrust include: design representations, computational reasoning, systems modeling and engineering, engineering education, collaborative design, and data/knowledge management.

CAREER: Student Motivation and Learning in Engineering

Abstract

This project seeks to help educators understand factors contributing to engineering students' motivation to learn and perform academically, and to examine correlations between these factors and students' cognitive processes. Specifically, we are examining differences between student motivation factors in different engineering majors, and correlations between these factors and evidence of knowledge transfer when students are working on problems in contexts that are new to them. 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 first phase of this project involved identifying and understanding factors that contribute to engineering students' motivation to learn and succeed, and compare these for different student types (by demographics and choice of major). A quantitative study was conducted in which the Motivation and Attitudes in Engineering (MAE) survey was developed using achievement value as the theoretical framework. Three constructs were identified through factor analysis: Expectancy, Present Perceptions (students' perceptions of their present tasks in engineering studies), and Future Perceptions (students' perceptions of their future tasks as engineers). Survey responses over the course of the first year in engineering for a single cohort of students (n=959) were collected and tested for internal reliability and validity, and to analyze relationships between constructs and student retention and choice of major data two years later (n=424).

Comparison of constructs over the course of the first year in engineering showed a significant decrease in expectancy, and significant increases in student perceptions about present and future. Binomial regression analysis revealed that students' perceptions about the future were significantly positive predictors of persistence in engineering. The interaction between perceptions about the present and future was a negative predictor of persistence. No significant differences were observed in motivation construct values by gender. The MAE survey and an informal Beginning of Semester (BOS) survey (used to assess how students choose their majors) were examined for differences in engineering student motivation based on major. While no differences in any of the MAE survey constructs were observed by major, differences in individual survey items were examined between majors grouped by overall features (traditional versus interdisciplinary). Students in interdisciplinary majors placed greater importance on making a difference and the availability of scholarship money, while students in traditional majors valued engineering work and designing and building things.

This data is being used to identify appropriate frameworks for future research, such as extrinsic value (scholarship money), identity formation and possible selves (I know an engineer who I admire, or goal theory (benefiting society). These findings will help direct more in-depth qualitative research into student motivation, which will be followed by studies of how students with different motivational attributes transfer knowledge when working problems in contexts they have not seen before.

Introduction and Research Questions

Examining students' academic performance is perhaps the most common way to gauge student success, and to evaluate the effectiveness of instructional and programmatic reform and innovation. However, grades are not an all-encompassing representation of students' learning experiences. Student motivation is related to academic performance and behavior [1–3], but the relationship between motivation and cognition, particularly in engineering, has not been examined in a way that is useful to practitioners. Motivation is a major factor in students' progress towards critical thinking and solving problems [1,2], skills that are commonly identified as important in preparing students for the ever-changing global challenges they will face as practicing engineers. Understanding relationships between motivation and problem solving could help engineering educators address challenges including increasing interest in engineering, and preparing students to become effective problem solvers.

The purpose of this study is to answer the following 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?

Theoretical Framework

This study examines the development of critical thinking and problem-solving skills through the lens of motivation theory. Motivation theories incorporate a wide array of contributing factors; modern theories most relevant to engineering pertain to goals, values, and expectations [4]. Expectancy x Value models of motivation [5], in particular a model refined by Eccles et al. [6], posit that expectations of success and the value placed on success determine motivation to achieve, and directly influence performance, persistence, and task choice. Expectancy of success is defined as one's beliefs about competence in a domain; it is not necessarily task-specific. Aspects of instrumentality capture how students perceive the importance of what they are doing in class relative to their future careers [7–9]. Students' expectancy is based partly on their self-efficacy [10], in addition to their perceptions about the difficulty of the goal, their prior experience, and peer encouragement from others [4]. Students with high self-efficacy use more cognitive and metacognitive strategies as well as self-regulatory strategies such as planning, monitoring, and regulating [11]. Achievement motivation, which encompasses students' attitudes about their abilities and tasks, can elucidate student choices related to persistence in engineering, solving problems, and the value of tasks encountered in an engineering environment [12]. Achievement motivation serves as a useful framework for the examination of research questions related to students' attitudes about pursuing engineering, and how these factors affect students' learning experiences.

Phase 1: Identifying Relevant Factors Contributing to Engineering Student Motivation

In the first phase of this project, a survey to assess first year students' motivation to pursue engineering studies was developed based on achievement motivation theories. A Motivation and

Attitudes in Engineering (MAE) survey was developed with three constructs: expectancy, or students' expectations for successfully completing tasks in their engineering studies [12], perceptions about future tasks/goals in engineering ("Future"), and perceptions about present tasks/goals in engineering ("Present"). The latter two constructs are supported by the Future Time Perspective theoretical framework [13]. The 34 item Likert-scale survey was tested and validated with first year engineering students [14]. Sample questions within each construct are included in Table 1.

Table 1: Sample items within each of three Motivation and Attitudes in Engineering (MAE) survey constructs.

Construct	# of Items	Sample Items
Expectancy (E)	12	I believe I will receive an excellent grade in this engineering course.
		The course work in engineering classes is easy.
		I am certain I can understand the most difficult material presented in the readings for this engineering course.
Perceptions of Future (F)	11	I am confident about my choice of major.
		I want to be an engineer.
		My interest in engineering outweighs any disadvantages I can think of.
Perceptions of Present (P)	11	I will use the information I learn in my engineering course in other classes I will take in the future.
		The university is preparing me well to become an engineer.
		I am being exposed to new ideas in my engineering courses.

Survey reliability and validity were established through factor analyses (exploratory and confirmatory) and comparisons of results to results from the literature. Responses over the first year in engineering were collected for a single cohort of students. Data on choice of major one year later were used to compare students who did and did not remain in engineering, and to develop a predictive model of persistence.

Over the course of the first year in engineering there was a significant decrease in Expectancy ($p<0.001$), and significant increases in Future ($p<0.001$) and Present ($p<0.001$) perceptions. Binomial regression revealed that Future perception was a significant positive predictor, and the interaction between Present and Future perceptions was a significant negative predictor, of persistence in engineering. First year engineering students whose perceptions about the future are more positive are more likely to persist in engineering. Perceptions about the present are only impactful when interacting with perceptions about the future. Engineering educators should address factors contributing to students' understanding of their future in engineering to maximize student persistence. Appropriate learning activities could include assignments in which students explore their future profession, or having students shadow practicing engineers. Results from this study have been prepared for publication, and are currently under review by the *Journal of Engineering Education*.

Results from the MAE survey were further analyzed with respect to correlations between motivation factors and chosen major [15]. Since no significant differences between chosen majors (from among 9 available choices at our institution) were found for any construct, majors were grouped as traditional (mechanical, electrical, civil, chemical, and industrial) and interdisciplinary (material science, environmental, computer, ceramic, biosysytems, and bioengineering). Traditional majors were defined as those with a subject-specific test on the Fundamentals of Engineering exam [16]. Interdisciplinary majors draw from a more emergent body of knowledge compared to the well-defined canon of knowledge for established, traditional majors. While no significant differences were found between these two groups of disciplines for any of the three survey constructs (Expectancy, Present and Future), statistical differences were found for individual items (Table 2). The findings showed that students in newer, more interdisciplinary majors struggle less in their courses, value introductory courses less, do not feel they work as hard, and expect better grades than those in established, traditional majors.

Table 2: Motivation, Attitudes, and Expectancy (MAE) survey results, on a scale from 0 (strongly disagree) to 5 (strongly agree). Survey items from Present (P) and Expectancy (E) constructs showed significant differences between traditional and interdisciplinary engineering groups. *p<0.05

Construct	MAE Survey Item	Traditional	Interdisciplinary
E	I am struggling with my college courses. (Reverse coded)	3.27	3.59*
P	I will use the information I learn in this engineering course in the future.	3.68	3.93*
E	I am having to work harder than many of the other students in my classes. (Reverse coded)	2.84	3.13*
E	I believe I will receive an excellent grade in this engineering course.	3.64	3.90*

Additional aspects of student motivation were examined through an informal Beginning of Semester (BOS) survey designed to understand student major choice. The results of the BOS survey (Table 3) indicate that traditional engineering students prefer to design and build things and are more likely to think engineers do interesting work, while interdisciplinary students were more likely to report that there is more scholarship money available for engineering majors, and that as engineers, they will have opportunities to benefit society.

Table 3: Beginning of Semester (BOS) survey results. Students were asked to rank the following reasons in response to the question, "Please rank the following reasons you wanted to pursue engineering, on a scale of 1-5, with 1 = no influence, 5 = top reason." *p<0.05, **p<0.001

BOS Statement	Traditional	Interdisciplinary
More scholarship money available	1.64	1.84*
Opportunities to benefit society	3.55	3.75*
Engineers do interesting work	3.86	3.69*
I like to design and build things	4.10	3.52**

These results, while important, are limited. The MAE survey was developed to inform student persistence in engineering, and thus its constructs are not as useful for informing differences in choice of engineering major. While the BOS survey has issues with item design features limit the ability to consistently interpret student results. Further elucidation of motivational differences between engineering disciplines will be achieved through more in-depth qualitative research (i.e. developing interview questions and quasi-experimental designs), which will allow for examination of how these differences manifest themselves in terms of student learning experiences in different disciplines.

Phase 2: Pilot Study of Correlations between Motivation and Learning

The Motivated Action Theory (MAT) is a theoretical framework describing the interactions between motivation and learning using self-goals, principle goals, goal orientation and actions [17]. However, the MAT model does not specify significant interactions between the different levels and components of the model. This pilot study attempts to empirically test possible connections between students' perceptions about their motivations related to engineering studies, and actions taken when solving a problem in a first year engineering course.

Out of the students who completed the MAE survey during their freshman year at our institution (n=959), problem solving data was available for three worked problems for a subset of students (n=31) within their first year engineering course. These problem solutions were analyzed in terms of cognitive and metacognitive tasks and processes as part of a separate funded project (NSF award # EEC-0935163, "CU Thinking"). Solutions were coded using a validated coding scheme [18] based on a theoretical framework of process activities used during problem solving in mathematics: knowledge access, knowledge generation and self-management [19]. Errors were classified as conceptual, mechanical, or management, and final solution accuracy was classified as correct, correct but missing units, or incorrect. Important internal process measures were identified through the analysis of coded data; out of the possible 28 internal process measures, six related to cognition and metacognition were selected for this pilot study. These are shown in

Table 4 below, and represent those processes that lead to successful solutions, or when missing, resulted in inefficient problem solving. Most process measures were represented as binary (either present or not), except for strategy. Using a structure adapted from Jonassen, strategies were assigned values equating to 3 levels: low (plug and chug and guess and check), intermediate (problem decomposition/segmentation and means-end analysis), and high (chunking/clustering and forward chaining) [20]. In addition to internal process measures, outcome measures were also analyzed; these evaluate whether the process is producing the desired results [21]. Out of six outcome measures (summaries of final results), two were used to analyze the data: time to completion and solution accuracy.

Table 4: Problem Solving Process Measures and Outcome Measures Included in the Analysis of Correlations Between Motivation and Problem Solving (Pilot Study, n=31)

Measure	Definition
Internal Process Measures	
Explicitly identifying unknown value	Students identified the variable or quantity for which they were solving
Explicit problem definition	Students restated the problem in their own words, identified assumptions, and identified constraints
Explicit visual representation	Solution contained a graphic representation of the problem and/or related variables within the problem
Solution strategy	Overall approach and method students used to solve the problem (e.g. means-ends analysis, problem segmentation, etc.) [22], or an apparent lack of strategy (e.g. plug and chug, guess and check) [23]
Explicitly identifying knowns and equations	Students identified known values and equations, whether or not they were provided in the problem description
Sensitivity	How well students recognize and correct errors in their work; takes into account rates of committing errors, correcting errors, and making "corrections" when no errors are actually present; can be conceptualized as a "signal to noise" ratio
Outcome Measures	
Time to completion	Total time for students to complete problem
Solution accuracy	Correct or incorrect final answer, or correct numerical answer but missing/inappropriate units.

Problem solutions were collected for three well-defined story problems that covered topics of efficiency, circuits, and pressure. All were structured enough for first year engineering students, but ill-defined enough to elicit students' problem-solving strategies upon analysis. The efficiency problem was the most complex and its context (solar power) was new to students. The circuits problem involved a "rule use/rule induction" portion (one correct solution but multiple rules governing the process) [24]. The pressure problem involved multiple unit conversion and derivation steps, but it was the least difficult conceptually.

All problems had a constrained context, included pre-defined elements (problem inputs), allowed multiple predictable procedures or algorithms, and had a single correct answer [20]. Students completed problems on tablet computers using custom-designed software that digitally records ink strokes and erasures, which can be replayed and coded directly in the application at any point in time in the data [25]. The software enables codes to be associated with specific ink strokes within the problem solution, even in portions that were later erased. Temporal data is also recorded, allowing calculations of time to completion and relative timing of various activities within the work.

Correlations between motivation constructs and problem solving performance measures (internal processes and outcomes) were analyzed using a Spearman rank-order correlation test, with pairwise p-values. Spearman rank-order correlation transforms non-parametric data into rank order for analysis. Probabilities (p-values) were corrected for multiple inferences using the Holm-Bonferroni method to reduce the possibility of committing a type I error [26], and a significance level of $\alpha=0.05$.

Results from the Spearman rank-order correlation tests showed students' ability to identify unknowns was the only performance measure correlated to motivation, specifically future motivation ($\rho=0.57$, $p=0.0225$). The correlation between these measures could indicate that students who have a more positive attitude towards their future as engineers are more likely to identify what they need to know. This correlation was significant only for the solar efficiency problem; there were no significant correlations between performance measures and motivation in the other two problems. Correlations comparing solution accuracy and time to completion to motivation showed only one significant result: future motivation was correlated to time to completion for the pressure problem ($\rho=0.38$, $p=0.0373$). This correlation was not evident in the other two problems, but it may be an indication that students who have a more positive attitude towards their future as engineers spend more time working through a problem.

The limited findings of this analysis can be attributed 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 results showed that the motivation factors significantly change over the course of an academic year [14]. Second, the level of guidance and structure typical for first year engineering problems limits the depth and variability of students' cognitive and metacognitive processes revealed in their solutions. Attributes of student motivation may be correlated with higher level cognitive processes, but first year students are either not likely to demonstrate these within the problems included in this analysis, and/or may not have the experience to actually use them. Third, the 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 [14]. These do not adequately encompass the many factors that contribute to student motivation, such as identity, or extrinsic factors such as those related to future employment or compensation.

While the results of this pilot study revealed few significant correlations between motivation and problem solving processes, results will be used to direct future explorations. More complex and open-ended problems designed to introduce new contexts will be used to elucidate how students transfer knowledge gained in previous learning environments to new situations [27–29]; this may relate to students' future perceptions about being engineers more significantly than problem solving processes. Future studies will focus on upper level engineering students, who are pursuing major-specific courses.

Summary of Phase 1 and Phase 2 Results

In work to date we have shown that students who persist in engineering have different motivation profiles than those who do not (higher future perceptions). We have also demonstrated a shift in students' motivational profiles over the course of an academic year (decreased expectancy, increased future and present perceptions). Further research demonstrated that expectancy and future time perspective frameworks may be limited at identifying motivational differences between engineering majors, but they do show differences on course related items such as, "I am struggling in this course." and "I am having to work harder than other students." Additionally, the relationship between students' cognitive output and their motivation was examined using their solutions to first year engineering problems. The results from this pilot study indicate that student perceptions of the future are correlated to their ability to identify unknowns and the amount of time spent solving a problem.

The Motivation and Attitudes in Engineering (MAE) survey presented here was significant in that it helps define factors contributing to the achievement motivation of first year engineering students to persist in an engineering course of study. The survey was partially derived from multiple other validated surveys, which have been applied in similar studies. The survey was initially developed based on a E x V constructs, and results of the survey aligned closely to that of the FTP achievement motivation theory that considers temporal factors. The observed decrease in Expectancy over first year is similar to results found by other researchers [30,31]. Hutchison-Green et al. found that first semester engineering students base their beliefs about self-efficacy, which is related to expectancy, on comparisons to the performance of their peers, and their perception that they work or learn slower than their peers can lead to a drop in self-efficacy[31]. Jones et al. examined first year engineering students' achievement and career plans, and found that students' perceptions about their abilities decreased over the course of the first year [30]. In our study, increases were observed in students' perceptions of the Future and Present, which are important in terms of what a first year program offers to students and what students are expecting from their education. The first year courses introduce students to different fields of engineering through contextual problems, guest speakers, tours with engineering departments on campus, and various career-related activities that would inform students' perceptions of their futures as engineers.

The analysis revealed that a student's Future perception has a significant influence on the probability of his or her persistence in an engineering major two years into college. The fact that Present perception has a negative effect on persistence was initially surprising. However, subsequent analysis identified this to be a case of an interaction between Future and Present perceptions. This interaction may be explained as those students who are focused on the value of achieving success in their present tasks, surpassing their focus on what they are likely to achieve in the future, will be more inclined to change majors in order to achieve their present goals (passing classes, maintaining a high GPA, etc.). However, Present perception has minimal impact on students whose perceptions of the Future are high as well. These findings were anticipated by Raynor [32], whose research in achievement motivation argued for two types of goal paths: open and closed. A “closed” path to a goal exists when students perceive the completion of a short term goal as the “end” of their path with no connection to future goals. The “open” path is where short-term goals are connected to other future goals and the “end” of the goal path is not specified. Raynor and others have demonstrated that open goal paths provide stronger motivational incentives for achieving the short term goals on that path than closed goal paths. This study provides similar evidence: if students are overly focused on tasks or goals in the present, they are on a “closed” goal path as described by Raynor; if they are focused on both present and future tasks or goals, they are on an “open” goal path. The study identifies that Future perception is a critical motivational construct, which could be used to maximize student persistence. In addition this work begins to establish the effect of motivation in problem solving scenarios, showing that students with lower perceptions of the future (an increased likelihood of a closed path goal) are less likely to use problem solving techniques of other successful students in their courses. Prior research by Matusovich et al. found that attainment value can play a critical role in students’ choices to persist in engineering, and suggest that educators strive to increase students’ attainment value by focusing on factors such as identity that contribute to value beliefs [33]. The findings of this study complement this prior work, as they reinforce the need to examine the temporal orientation of students’ beliefs. To understand the full influence that value and identity can have on student persistence, we need to be clear whether present or future perceptions or values are under consideration.

In order for students to effectively apply their intellectual resources in their educational experiences, they must be motivated to do so. Educators should understand factors in students’ development that contribute to motivation (e.g. expectations, values, goals, and attitudes) as well as their cognition and academic performance. Past research has addressed the affective and cognitive domains independently, but there has been little work on how affective factors are related to learning for engineering students. Understanding these relationships will address the greatest 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.

Future work

We plan to collect additional interview data from the major specific sophomore engineering classes in Bioengineering or Mechanical Engineering programs at our institution, to further explore the connections between student problem solving and motivation. Selected problems will be administered to observe knowledge transfer (an aspect of problem solving) and differences in motivational factors resulting from immersion in a student’s major.

Data on students’ perceived self-efficacy with respect to problem solving (e.g. metacognition and transfer) will be collected using a modified version the validated Attitudes and Approaches to Problem Solving Survey (AAPS) [34]. This instrument was tested and validated with physics undergraduate and graduate students, and faculty, and has been adapted for engineering for this study by replacing the word “physics” with “engineering” in the survey questions. We have modified the survey to elicit understanding of problem solving self-efficacy [35] through rewording of the questions to prompt students with statements they feel they can or cannot perform. The MAE survey is in the form of Likert scale questions, while the AAPS adaptation reports student responses in a nominal format (from 0-100). The data collected will be analyzed to purposefully select students for in-depth interviews to determine the connections between motivation and knowledge transfer during problem-solving. We plan to correlate student motivation with the development of problem-solving skills and the ability to transfer knowledge, and track changes in these correlations over time. The ultimate goal of this work is to develop a robust instrument to assess engineering students' motivation throughout the undergraduate experience, based on an amalgamated motivation theory for undergraduate engineering students grounded in the data.

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References:

1. Dweck CS, Leggett EL. A social-cognitive approach to motivation and personality. Psychological Review [Internet]. Psychology Press; 1988;95(2):256–73. Available from: http://doi.apa.org/getdoi.cfm?doi=10.1037/0033-295X.95.2.256
2. Crawley FE, Kobala Jr. TR. Attitude research in science education: Contemporary models and methods. Science Education [Internet]. 1994;78(1):35–55. Available from: http://eric.ed.gov/ERICWebPortal/recordDetail?accno=EJ493797
3. Pintrich PR. Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. Journal of Educational Psychology [Internet]. American Psychological Association; 2000;92(3):544–55. Available from: http://doi.apa.org/getdoi.cfm?doi=10.1037/0022-0663.92.3.544
4. Svinicki M. Learning and Motivation in the Postsecondary Classroom. Bolton, MA: Anker Publishing; 2004.
5. Wigfield a, Eccles J. Expectancy-Value Theory of Achievement Motivation. Contemporary educational psychology [Internet]. 2000 Jan [cited 2012 Jul 16];25(1):68–81. Available from: http://www.ncbi.nlm.nih.gov/pubmed/10620382
6. Eccles JS, Adler TF, Futterman R, Goff SB, Kaczala CM, Meece J, et al. Expectancies, values, and academic behaviors. In: Spence TJ, editor. Achievement and Achievement Motivation. San Francisco, CA: W. H. Freeman; 1983. page 75–146.
7. Husman J, Pitt Derryberry W, Michael Crowson H, Lomax R. Instrumentality, task value, and intrinsic motivation: Making sense of their independent interdependence. Contemporary Educational Psychology [Internet]. 2004 Jan [cited 2012 Jul 16];29(1):63–76. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0361476X03000195
8. Andriessen I, Phalet K, Lens W. Future goal setting, task motivation and learning of minority and non-minority students in Dutch schools. The British journal of educational psychology [Internet]. 2006 Dec [cited 2012 Dec 9];76(4):827–50. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17094888
9. Simons J, Dewitte S, Lens W. The role of different types of instrumentality in motivation, study strategies, and performance: know why you learn, so you'll know what you learn! The British journal of educational psychology [Internet]. 2004 Sep;74(3):343–60. Available from: http://www.ncbi.nlm.nih.gov/pubmed/15296544

10. Bandura A. Social cognitive theory. Annals of Child Development. 1989;6:1–60.
11. Pintrich PR. The role of motivation in promoting and sustaining self-regulated learning. International Journal of Educational Research [Internet]. 1999 Jan;31(6):459–70. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0883035599000154
12. Eccles JS, Wigfield A. Motivational beliefs, values, and goals. Annual review of psychology. 2002 Jan;53:109–32.
13. Husman J, Lens W. The role of the future in student motivation. Educational Psychologist. Taylor & Francis; 1999;34(2):113–25.
14. Benson L, Morkos B, Husman J. Motivation of First Year Engineering Students and Its Relation to Persistence in Engineering. Journal of Engineering Education. 2013; under review.
15. Kirn A, Morkos B, Benson L. Work in Progress: How Differences in Student Motivation Characterize Differences between Engineering Disciplines. Frontiers in Education Conference, 2012. 27th Annual Conference.'Soaring to New Heights in Engineering Education.' Proceedings. [Internet]. Seattle, WA: Institute of Electrical and Electronics Engineers Inc.; 2012. page 452–3. Available from: www.fie2012.org
16. National Council of Examiners for Engineers and Surveyors [Internet]. [cited 2012 Jun 26]. Available from: http://www.ncees.org/exams/fe_exam.php
17. DeShon RP, Gillespie JZ. A motivated action theory account of goal orientation. The Journal of applied psychology. 2005 Nov;90(6):1096–127.
18. Grigg S, Benson L. Design and validation of a coding scheme for analyzing problem solving processes of first year engineering students. Journal of Engineering Education. 2013;under review.
19. Wong RM., Lawson MJ, Keeves J. The effects of self-explanation training on students' problem solving in high-school mathematics. Learning and Instruction [Internet]. 2002 Apr;12(2):233–62. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0959475201000275
20. Jonassen DH. Learning to Solve Problems. San Francisco, CA: Pfeiffer; 2004.
21. Harmon P. How Do You Measure Processes ? Business Process Trends Monthly Email Advisor. 2008;6(8):2–3.
22. Nickerson RS. The teaching and thinking of problem solving. In: Sternberg RJ, editor. Thinking and Problem Solving. 2nd ed. San Diego, CA: Academic Press; 1994. page 409–49.
23. Wankat P. Reflective Analysis of Student Learning in a Sophomore Engineering Course. Journal of Engineering Education. 1999;88(2):195–203.
24. Jonassen DH. Toward a Design Theory of Problem Solving.pdf. Educational Technology Research & Development. 2000;48(4):63–85.
25. Bowman D, Benson L. MuseInk : Seeing and Hearing a Freshman Engineering Student Ink and Think. ASEE Annual Conference Proceedings. Louisville, KY: American Society for Engineering Education; 2010. page 0–6.

26. Holm S. A simple sequentially rejective multiple test procedure. Scandinavian journal of statistics. 1979;(December 1977):65–70.
27. Rebello N, Zollman D, Allbaugh A, Engelhardt P V., Gray KE, Hrepic Z, et al. Dynamic transfer: A perspective from physics education research. In: Mestre JP, editor. Transfer of Learning from a Modern Multidisciplinary Perspective. Greenwich, CT: Information Age Publishing Inc.; 2005. page 217–50.
28. Bransford J, Schwartz D. Rethinking transfer: A simple proposal with multiple implications. Review of research in education. 1999;24:61–100.
29. Lobato J. Alternative perspectives on the transfer of learning: History, issues, and challenges for future research. The Journal of the Learning Sciences. Taylor & Francis; 2006;15(4):431–49.
30. Jones B, Paretti M, Hein S, Knott T. An Analysis of Motivation Constructs with First-Year Engineering Students: Relationships Among Expectancies, Values, Achievement, and Career Plans. Journal of Engineering Education. 2009;99(4):319–36.
31. Hutchison-Green M, Follman D, Bodner G. Providing a Voice : Qualitative Investigation of the Impact of a First-Year Engineering Experience on Students' Efficacy Beliefs. Journal of Engineering Education. 2008;97(2):177–90.
32. Raynor J. Future orientation and motivation of immediate activity: an elaboration of the theory of achievement motivation. Psychological Review. 1969;76(6):606–10.
33. Matusovich H, Streveler RA, Miller RL. Why Do Students Choose Engineering ? A Qualitative, Longitudinal Investigation of Students' Motivational Values. Journal of Engineering Education. 2010;99(4):289–303.
34. Mason A, Singh C. Surveying graduate students' attitudes and approaches to problem solving. Physical Review Special Topics - Physics Education Research [Internet]. 2010 Dec [cited 2012 Aug 21];6(2):1–16. Available from: http://link.aps.org/doi/10.1103/PhysRevSTPER.6.020124
35. Bandura A. Guide for constructing self-efficacy scales. Self-efficacy beliefs of adolescents. Information Age Publishing; 2006. page 307–37.