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Engineering Students' Perceptions of the Future: Exploratory Instrument Development

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Abstract:

The purpose of this research paper is to understand how engineering students' long-term motivation, as previously described qualitatively in terms of student perceptions of future goals, can be explained quantitatively. Future Time Perspective (FTP) served as the theoretical framing for this work, and provides a model for how students' perceptions of the future can guide their actions in the present. The guiding questions for this work seek to understand how qualitative results about engineering students' FTP generalize to a quantitative survey for a different student population. To answer this research question, an exploratory instrument development mixed methods study with parallel sampling was conducted. Participants in the qualitative portion of the study, second year engineering students (n=9) at a southeastern land-grant institution, were interviewed about their perceptions of the future, perceptions of the present, and the interconnections between the future and present. Qualitative results informed development of a survey about student motivation. Participants in the quantitative portion of the study were from a western land grant institution. Students in a first year engineering course (n=360, response rate 52.8%) completed the Likert-type survey that assessed motivation related to their goal orientations, expectancies, and FTPs. Results of exploratory factor analysis indicated seven unique factors, three of which were related to FTP (perceptions of the future, perceived instrumentality of present tasks, and the influence of the future on the present). A k-means cluster analysis was then performed using these three FTP factors to determine what groupings may exist based on students' FTPs. The cluster analysis indicated three unique groupings that showed similar characteristics to the three groupings found through qualitative analysis. Results of this mixed methods study indicate that previous qualitative results are generalizable to a different engineering population. This work brings us a step closer to developing a valid instrument to assess motivation based on FTP for use alongside performance assessments, allowing for better understanding of how the affective domain influences cognitive performance in engineering.

Introduction:

The study of student motivation in engineering has developed around one of two conceptualizations of motivation: 1) short-term task-specific motivation and 2) student motivation toward long-term goals. Task-specific motivation seeks to understand student motivation for performing and completing a specific task such as problem solving or design.[1] Results have indicated that students with higher self-efficacy (a task-specific motivation[2]) have been shown to have improved learning and understanding in introductory engineering courses.[3] Work focused on long-term goals, such as graduating with an engineering degree, has shown that students who have higher expectancies for their performance in engineering have significantly higher grade point averages (GPAs).[4,5] Connections between these two scales of motivation have been proposed, yet little work has been done to examine how these levels are connected and influence one another.[6] The overarching purpose of our research is to understand the connection between multiple levels of student motivation and how these levels influence engineering students' actions and performance.

Previous qualitative studies from our research team indicated that the interactions of these levels of motivation directly influence students' perceptions of educational environments and how they approach engineering problems.[26] For this mixed methods research paper, we leverage previous research on students' perceptions of future goals and actions taken in the present to answer the research question: How well does engineering students' short- and long-term motivation explained qualitatively in one population translate to a quantitative analysis for a new engineering student population?

Theoretical Frameworks

This work utilizes the theoretical framework of *motivated action theory*,[6] which assumes that all student action is driven by a series of complex motivational drivers. Motivational drivers range from stable traits to unstable characteristics related to situational contexts. While motivated action theory rests its theoretical construction in goal orientation literature,[9] it does not provide a means of operationalizing the framework to understand the interconnected levels of student motivation. To this end, we apply theories of achievement motivation to explore aspects of student motivation that are relevant to their cognitive practices.

Long-Term Motivation: Expectancy x Value Theory

Students' motivations toward long-term goals are evaluated through Expectancy x Value theory (EVT), which focuses on the expectation of how one will perform on a task and how much one values a task or its outcomes.[10] EVT posits that three main criteria must be met for motivated action: a) With enough effort, the performance can be achieved; b) If achieved, performance will lead to desired outcomes; and c) Those outcomes will lead to satisfaction.[10] EVT research has shown that engineering students with higher expectations will have better academic performance, and those who see higher value for a task will persist longer on that task.[5] EVT has been developed to examine students' motivations toward long-term goals at a degree or course level.[10]

For this work, EVT was operationalized to assess expectancy, or how students expected to do in an introductory engineering course. Survey items evaluating expectancy are shown in Table 1.

Short-Term Motivation: Goal Orientation

The literature describes three types of goal orientation: mastery approach, performance approach,[12] and work avoid.[13] Mastery goal orientation is defined as holding knowledge and understanding as the main purpose for learning, while performance approach focuses on positive judgment from others as the main purpose for learning.[9] Studies have shown that both mastery and performance approach goals can be linked to outcomes of self-efficacy, expectancy, strategy use, and performance.[13] Performance approach goals and course performance have been correlated, while mastery goals are correlated with continued subject interest.[14] Students with a work avoid goal orientation try to evade work and prefer to work on academic tasks that are relatively easy and can be completed in a short amount of time.[15] This work avoid orientation that seeks to minimize academic effort has been linked with poor academic outcomes.[15] Research applying goal orientation frameworks often considers goals that are only proximal in time or short-term.

For this work, goal orientation items were adapted from Shell and Husman.[16] These items were originally created by Schraw, Horn, Thorndike-Christ, and Bruning[17] and were adapted to be measured using a scale developed by Dweck.[9] Survey items spanning the goal orientation constructs asked students to "Use the scale given (5 point Likert-type) to rate how important achieving each of the following is to you in this class from Very Unimportant to Very Important" followed by statements such as those found in Table 1.

Connections Between Long- and Short-term Motivation: Future Time Perspective

FTP has been applied to understand how varying perspectives of the future influence present action, thus providing a means of making connections between motivation at different time scales (i.e. long-term and short-term goals).[11] There are three dimensions to FTP: time orientation, perceived instrumentality, and perceptions of time. Time orientations range from past-oriented to future-oriented. Perceived instrumentality focuses on how students view a current task as being useful for reaching a desired future goal. Students' perceptions of time can range from positive (i.e., time will make things better) to negative (i.e., current living standards will not improve over time). The three elements of FTP create connections between more stable long-term career goals and short-term tasks to understand the actions taken by students. Students with positive FTPs have been shown to possess and use traits related to increased learning, retention, and valuing of tasks.

For this study, FTP was operationalized to assess students' time orientations in terms of their perceptions of the future in relation to their engineering degree and their desire to be an engineer, and their perceived instrumentality of present tasks. It was assumed that all students who have entered into a college-level engineering program consider graduating with a degree to be part of their future; thus, the time point around obtaining an engineering degree, including steps towards becoming an engineer, was chosen as the future time point under consideration. Student perceptions of the future were evaluated in terms of how students viewed the future in relation to their engineering degree and their desire to be an engineer. In addition to time orientation and perceived instrumentality, students' perceptions of the influence of the future (i.e. their views on the engineering field) on their activities in their present (i.e. in their engineering course). Examples of survey items evaluating FTP constructs are shown in Table 1.

Methods:

To address the research question for this study (how well qualitative results on students' FTP translate to a quantitative analysis with a second population of students), an exploratory instrument development mixed methods study with parallel sampling was conducted. Parallel sampling refers to using two or more similar subgroups for comparison. The two subgroups used in this study have similar demographics with some variation in minority composition. Both subgroups were within their first two years of the engineering degree and were thus removed from the strong cultural influences of disciplinary homes. While assuming that these two populations are similar is not without its limitations, the immersion of the lead author in both cultural environments and reflective conversations between the authors on a weekly basis allows us to make this assumption with confidence. Reasons as to why this assumption would not be valid (e.g., background demographics, institutional cultures, and other similar factors) are not explored and are grounds for future work. Exploratory instrument development seeks to determine how qualitative results generalize quantitatively.

Participants

Qualitative interviews of engineering students (n=9) were collected from a southeastern land-grant institution. Interviews focused on students' perceptions of the future, perceptions of the present (perceived instrumentality), and the interconnections between future goals and present actions. The results of this work indicated three unique student profiles based on their FTPs and have been described previously.[18]

For the quantitative portion of this work, engineering students at a western land grant institution in fall of 2014 who were enrolled in a first year engineering course required of all engineering majors (except computer science and engineering) were invited to participate (n=682). Students completed the optional survey (n=360, 52.8% response rate) during the first week of class in laboratory sessions of the course.

Instrument

Motivation was assessed using the Motivations and Attitudes in Engineering that had been previously created, refined, tested, and validated at a southeastern land-grant institution in a first year engineering program. The survey items were originally designed to assess student persistence in engineering, through students' perceptions of present actions ("Present"), futures as engineers ("Future"), and their expectations of successfully completing tasks in their engineering studies ("Expectancy"). Additional Motivations and Attitudes in Engineering items focus on assessing student perceptions of their metacognition (a proxy for problem solving) and goal orientations. The construct of metacognition was not included in the present study as it was beyond the scope of the research question, which related more specifically to FTP. Sample items for each of these constructs are shown in Table 1. Previous work with this survey has shown that students with positive perceptions of the Future are more likely to persist in engineering.[18] Additionally, results using this survey have also indicated differences in students' problem solving approaches based on their perceptions of the future.[19] Results of qualitative work justify the continued use of these constructs as students indicated connections between these constructs in their interviews.[18]

Varying from previous administrations of the Motivations and Attitudes in Engineering, items were added to the survey based on the results of previous qualitative work that differentiated students based on how their FTPs influenced their problem solving in their engineering course.[18] This construct was labeled "Influence of Future on Present". It was hypothesized that additional items related to these findings would allow for better characterization of engineering student motivation based on their future time perspectives.

The final instrument consisted of 40 items with additional demographic questions placed at the end of the survey. All items were on a 5 point Likert-type scale from "Strongly Disagree" to "Strongly Agree".

Table 1. Constructs and example items from the Motivations and Attitudes in Engineering included in this study.

Construct	**Example Items**
Expectancy	I expect to do well in this engineering course. I am confident I can do an excellent job on the assignments and tests in this engineering course.
Mastery Approach	[Importance of] really understanding this course material.
Performance Approach	[Importance of] remembering enough from this class to impress people.
Work Avoid	[Importance of] not having to work too hard in this class.
Perceptions of the Future	My interest in engineering outweighs any disadvantages I can think of. I want to be an engineer.
Perceived Instrumentality	I will use the information I learn in this engineering course in the future. What I learn in my engineering course will be important for my future occupational success.
Influence of the Future on the Present	My future career influences what I learn in this course.

Analyses

Data Cleaning

All responses for students under the age of 18 years and those who did not answer the question about their age were removed. The number of survey responses left in the data set was reduced to 332 after this step. All other data cleaning occurred as part of the analytic process and is outlined throughout each analysis.

Exploratory Factor Analyses

Exploratory factor analysis (EFA) was conducted for the survey in its entirety to assess validity for the new population and with new items added. Scree plots and literature for each framework were used to determine the numbers of factors to test during the analysis. Items that loaded below 0.4 were removed from the analysis.[21] This analysis was run in R using the nFactor package with a Promax rotation as it allows for correlation between variables.[20]

Cluster Analyses

Cluster analysis was used to understand how elements of students' FTPs that were found to be highly influential on student perceptions of present engineering tasks could be used to understand differing FTPs that engineering students possess. To run cluster analyses and create average factor scores based on EFA results, items that were reverse coded were recoded. Average factor scores were then calculated for each participant. Weighted averages using factor loading scores as multipliers were not used because the 0.4 cutoff was applied in the EFAs; eliminating all factor weights below 0.4 would lead to artificially over-weighting items. A k-means cluster analysis was used to group students after the determination of the appropriate number of clusters. This analysis was run in R using the Cluster and FPC packages.[20]

Results and Discussion:

Exploratory Factor Analyses

The results of the scree plot along with theoretical framing and previous survey administration support seven unique factors in this survey. When comparing seven factors to the potential factors from the literature, this number of factors appeared to allow for greater exploration of students' FTP, which was the goal of the additional survey items based on results of our qualitative phase of the study.

To determine the exact nature of the items loading on these seven factors, a series of EFAs were run, with items not loading after each run being removed and the analysis being repeated. This process was repeated until all remaining items loaded onto singular factors with no cross loading.

Results from the first two EFA runs indicated four items that did not load that were related to perceptions of the future: "My future career influences what I learn in this course", "Engineering is the most rewarding future career I can think of for myself", "There are multiple careers that I can imagine being rewarding for myself" and "Engineering allows me to explore multiple future careers." The latter two items relate to students' perceptions of multiple futures and may not be reliable in a survey that focuses on obtaining an engineering degree. These four items were removed prior to subsequent analysis.

The third factor analysis resulted in zero items that were cross-loaded or that did not load on a factor. Items related to Expectancy (from EVT)[10] loaded onto one factor. Items related to goal orientation loaded onto three factors as anticipated: mastery approach, performance approach and work avoid. Perceived instrumentality items, or students' perceptions of the usefulness of current tasks for the future, loaded onto one factor. This was a new construct for this survey but has been previously discussed in the FTP literature.[11] Students' perceptions of future career goals or perceptions of the future in engineering loaded onto one factor. One factor comprised items related to the influence of students' futures on their present actions. This construct is also new compared to previous administrations and helps to explain the interconnected levels of student motivations on different time scales. Only two items loaded in this factor. The factor loadings for these items were high, indicating that they load strongly, but having only two items in the factor limits future interpretive power of this construct in subsequent retesting due to the minimum requirements for confirmatory factor analysis.[22] Table 2 shows the constructs and numbers of items loading into each construct after the third and final EFA.

Table 2: The constructs and items that loaded onto them based on EFA analysis of the Motivations and Attitudes in Engineering Fall 14 survey data collected at a Western Land Grant Institution.

Factor Name	Number of Items in Factor
Expectancy	7
Mastery Approach	4
Performance Approach	7
Work Avoid	3
Perceptions of The Future	7
Perceived Instrumentality	6
Future on Present	2

Cluster Analysis

Our previous qualitative research conducted on engineering students indicated that students' perceptions of the future, perceived instrumentality, and influence of future goals on the present had strong influences on student problem solving.[18] These three factors combined to create engineering student FTPs.[18] Based on these previous results, the hypothesis is that three groups will emerge:

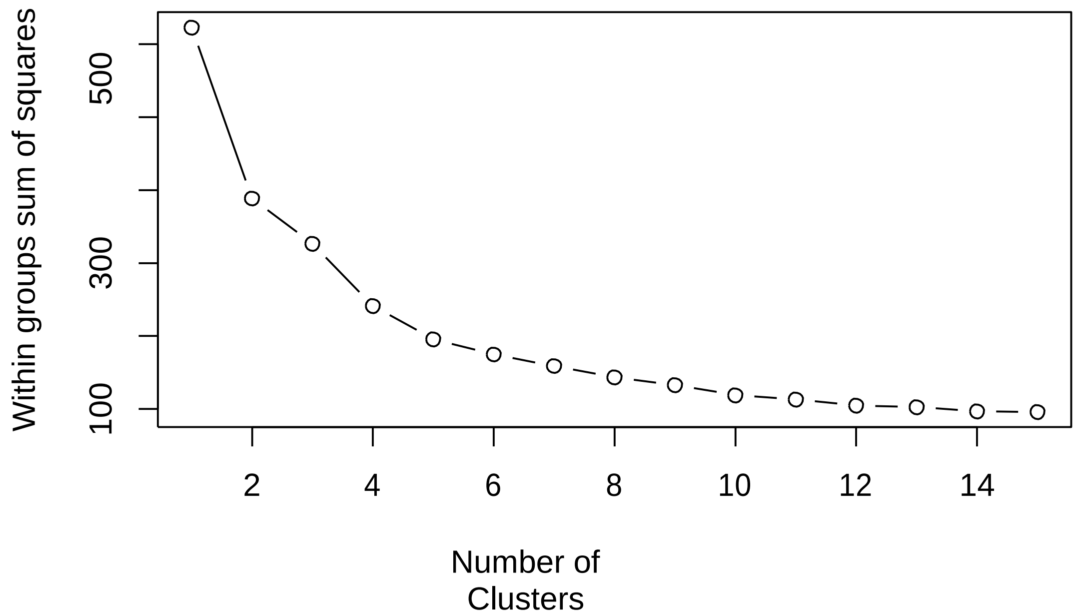
- Group 1: high future, perceived instrumentality and future on present scores
- Group 2: lower future scores than Group 1, and high perceived instrumentality and future on present scores
- Group 3: low future and future on present scores, but similar perceived instrumentality scores to Groups 1 and 2

These three FTP groupings were defined based on a limited sample in our qualitative study (n=9). This expanded quantitative sample provides a means of triangulating the previous results. Performing a cluster analysis provides an empirical means to determine if these FTPs exist for a large population of engineering students.

Clustering around Future Time Perspective Constructs

To find the number of clusters, a process similar to finding the number of factors in EFA is used (scree plot and literature related to the theoretical framework). Figure 1 shows the scree plot used to determine the number of clusters for this study.

Figure 1: Scree plot for determining the number of clusters within the survey data (n=332) based on three FTP constructs (perceptions of the future, perceived instrumentality and influence of future on present).



The results of the plot shown in Figure 1 indicate that two or three clusters are potentially appropriate for this data set. Both cluster models were tested to determine which model would explain a higher level of variance in student groupings and that would be supported by the literature on FTP. Results of a k-means cluster analysis for each test condition are discussed.

Results of the two cluster model (shown below in Figure 2) demonstrate that there are potentially two distinct clusters of students based on their FTPs. The model explains 83% of the variability between the points. Cluster 1 (on the right) displays a high range of variability in student responses with high numbers of outliers. This may indicate that the k-means analysis is over-generalizing student responses, thus leading to a loss of the differentiation between student FTPs.

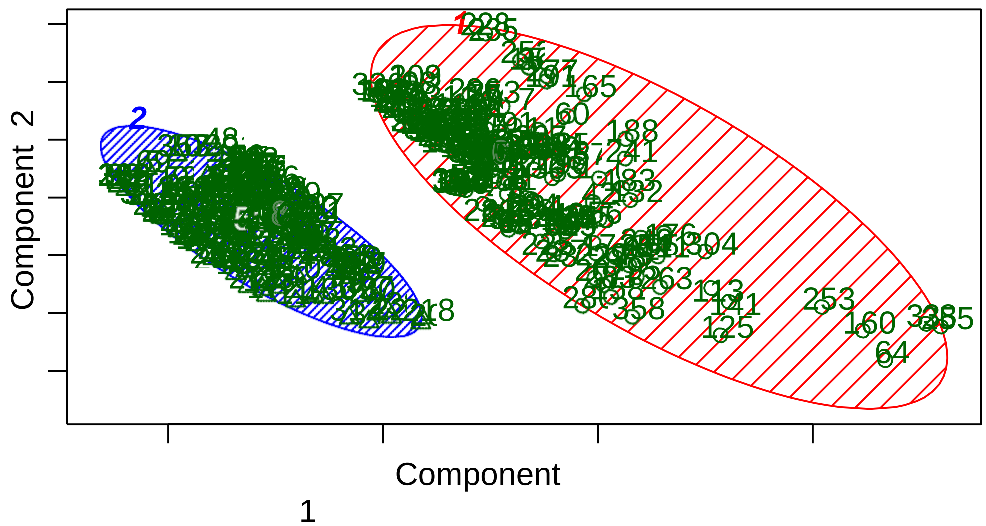


Figure 2: A two-cluster model of the three FTP factors using a k-means cluster analysis. This model accounts for 83.0% of the point variability within the data set.

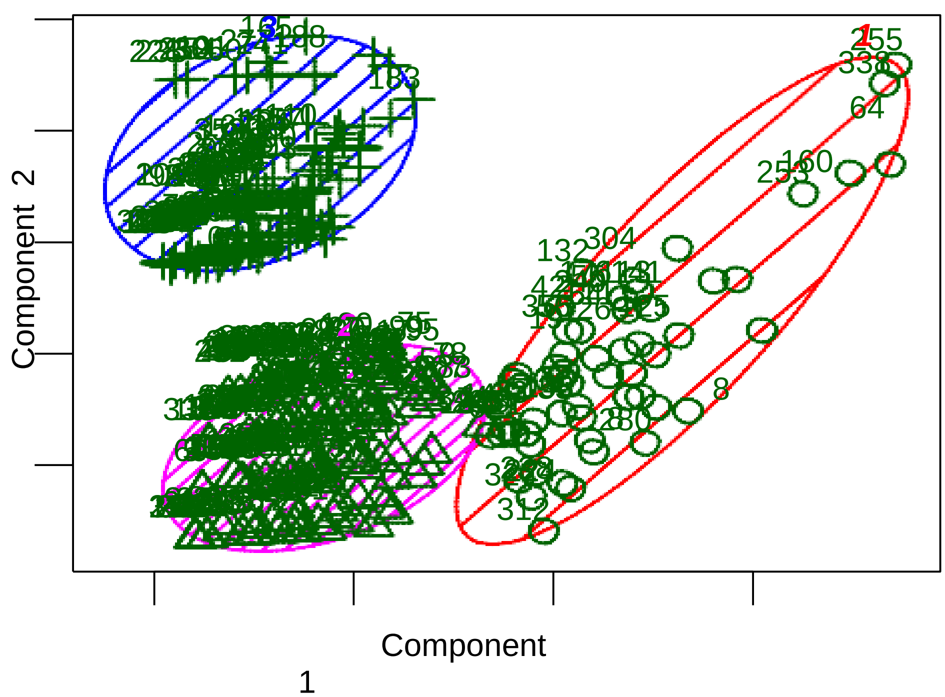


Figure 3: A three-cluster model of the three FTP factors using a k-means cluster analysis. This model accounts for 82.52% of the point variability within the data set.

Results of the three cluster model (shown above in Figure 3) explain 82.52% of the variance between points based on students' FTPs. This model demonstrates that one cluster (upper left corner) is highly distinct from the other two. The two remaining clusters are tightly grouped and appear closely related to one another, but do not overlap. This model closely aligns with our previous qualitative results and explains nearly the same amount of variance as the two cluster model. Cluster 3 in this model displays a wider range of variance in points, but has fewer students as outliers making it less likely to suppress variance in student FTPs than Cluster 1 in the two-cluster model shown in Figure 2. Based on the combination of the FTP theoretical framework, previous qualitative results[18] and the results of the cluster models, a three cluster model was selected for further analysis.

To better understand and characterize each cluster in terms of students' FTPs, average factor scores for each cluster were calculated. These results, displayed in Table 3, indicate that Cluster 1 (n=63) consists of students with low average factor scores for all three factors, and Cluster 2 (n=168) consists of students who have high average factor scores for all three factors. Cluster 3 (n=101) consists of students with high average factor scores for perceived instrumentality and perceptions of the future, and a low average factor score for future on present. Cluster 1 most clearly mirrors the students with limited FTPs as described in our previous qualitative findings. Students in Cluster 1 convey vague notions of their future in engineering and limited perceived usefulness of current tasks. Cluster 2 reflects students who have been described as having highly defined futures, strong perceptions of present task usefulness, and strong sense of influence of the future on their present activities. Cluster 3 most clearly mirrors the students with FTPs that don't project as far into the future as Cluster 2, but still see the instrumentality of present tasks. Qualitative analyses of data from these types of students show that they spent more time during the interview discussing tasks they are doing for their future rather than the influence of the future on the present.

Table 3. Average factor scores for each cluster from the three-cluster model.

Cluster	**Perceived Instrumentality**	**Perceptions of the Future**	**Influence of Future on Present**	**Description**
1	3.61	2.88	3.04	Low FTP Scores
2	4.58	4.23	4.23	High FTP Scores
3	4.49	4.21	2.51	High PI and Perceptions of the Future; low Influence of Future on Present

While these interpretations show similarities to previous work,[18] the data show that the differences between groups are not as strongly pronounced in the quantitative results as they were in the previous qualitative analyses. This could be due to several factors. First, students in this population were surveyed during their first week of classes, and may have answered questions differently than those in the qualitative portions of the study who were in their sophomore or first two weeks of their junior years of engineering and have gained greater understanding of engineering and engineering culture. Student responses on a quantitative instrument limit the depth and richness seen in interviews and as such may be missing the nuances seen in an interview about a student's perceptions. Third, the FTPs described in previous work were for a different population in terms of location and cultural environment. The subcultures within each environment can serve to shape students' perceptions of their goals and how they are reaching their goals. To understand how previous work applies to this population, interviews of students from each group at the western land-grant institution must be conducted.

Broader Connections to Previous Work and Implications for Practice:

While this work has furthered our research agenda seeking to understand student motivation and learning, this work also provides advances for engineering education. First, this work has further validated results for an instrument (Motivations and Attitudes in Engineering Survey) that allows the exploration of how student motivation across levels can explain variation in students' actions. Previous FTP work has shown that students who have less defined perceptions of the future do not see the value in current tasks and perceive current tasks as larger barriers than students with highly developed FTPs.11 Students without developed FTPs are more likely to use learning strategies that do not lead to learning and retention of knowledge. Additionally, students with limited FTPs are less likely to persist on tasks that present as barriers.[24] The lack of in depth learning and limited ability to persist touches on two long standing issues in engineering education.

The study of persistence in engineering has been long discussed as an issue through the metaphor of a leaky pipeline. While some work has indicated that the pipeline is beginning to be patched,[25] other work has indicated that the leaks are selective and allow for a greater outflow of students from underrepresented groups.[26] The long established history of engineering as a field for those who are white middle-class and male may make construction of engineering FTPs for minority students difficult when role models are limited or non-existent.[27] Understanding that students can actively construct new FTPs in engineering through guidance and structured reflection can provide instructors with tools to help minority students develop attitudinal profiles shown to be beneficial for pursuit of future goals.

The results of this work indicate that there is a limited range of FTPs in engineering. When comparing the results from this work and similar work by Raynor,[24] students with different FTP profiles may learn different content or skills despite receiving the same instruction. Understanding the differences that exist in students' FTPs can provide instructors with a tool to understand how to teach to these students in ways that may be more cross-cutting than pedagogies targeting specific groups in engineering, such as those defined by demographics, gender, race or ethnicity. If instruction in engineering education becomes increasingly targeted to student attitudinal profiles, then students may more readily develop skills for solving 21st century problems that continue to go unsolved in engineering.[28]

Conclusions and Future Work:

This study applied an instrument developed based on previous mixed-methods work on engineering students' levels of motivation translates to a quantitative study of the same motivation constructs with a larger engineering student population at a different institution. Results indicated that students' FTPs, expectancy, and goal orientations can be used to effectively describe variability in engineering student motivation. These motivations have been previously connected to student problem solving and learning. Future work examining the interactions of student motivation levels must expand to understand how these trends may or may not hold for subgroups within engineering, including unrepresented groups, and within different engineering disciplines rather than engineering as a monolithic discipline. Additionally, results of this work indicated instability of metacognitive survey items, and as such they warrant further exploration such that connections can be made between the affective domain and cognitive processes.

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