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Measuring First-Year Engineering Majors' Interest in Engineering

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Abstract

This evidence-based practice paper is focused on measuring the individual/maintained interest construct for first-year engineering students at a Southeastern university with a strong engineering program. A major contributing factor to ongoing low-level retention rates in STEM fields is the nature of many first- and second-year gateway courses, resulting in an undesirably large number of student attrition. The authors hypothesize first-year student experiences that significantly enhance interest in engineering, if effectively implemented, can outweigh the discouragement resulting from experiences in other early courses. Thereby students will be more likely to persevere through these courses and persist in engineering. Enhancing first-year engineering student retention is expected in turn to increase the number of people who obtain a degree in engineering.

The study discussed has been identified by the authors as a first step within a more expansive research agenda focused on the impact first-year student interest in engineering has on student retention. Data was collected from 424 first-year engineering students experiencing a relatively new course titled *Engineering Methods, Tools, and Practice II* (ENGR 111), that centers around a suite of hands-on makerspace-based activities. This quantitative data was procured using a slightly modified (for engineering context) 8-item, validated instrument focused on longer-term, maintained interest. The methods that follow were developed to explore a multi-subfactor depiction(s) (from literature) of maintained interest, including conceptualizing and analyzing student responses. Two associated research questions thusly addressed in this study are: 1) what is the strongest factor structure for measuring the construct of first-year engineering students' long-term, stable maintained interest in the choice of pursuing an engineering career?; and 2) how ***strong is the fit*** of theoretically-grounded ***structural models*** of the construct of first-year engineering students' maintained interest in engineering careers? Results show significant empirical support in utilizing a 3-factor model (discussed in detail below) to measure first-year engineering students' maintained interest in the engineering profession as a career choice.

1. Introduction

National retention rates in STEM undergraduate programs continue to average about 50% [1]. More specifically, there has been an undesirable decrease over the past several decades in the number of students persisting in *engineering* degree programs [2-3]. Increasing first-year engineering retention increases the number of engineering students earning undergraduate degrees, yet doing so has proven challenging because associated factors are multifaceted and not thoroughly understood [4-6].

Aptitude and work ethic certainly play a role in retaining students in the engineering pipeline. For example, several findings [e.g. 7] show that the challenges of the first-year gateway foundational calculus sequence can be significant factors in student attrition. However, research has shown that other individual constructs not only play a very influential role in engineering retention, but are potentially even more meaningful than aptitude and/or work ethic. A large-scale study by Seymour and Hewitt [8] found that students' choices to leave STEM majors were usually not due to poor aptitude or work ethic, but instead were more related to weakened perceptions of the reason(s) they chose that field in the first place. These types of constructs that contribute to student attrition can be traced back to the work of J.S. Eccles, the pioneer in the expectancy-value theory of motivation [9-11]. Eccles' theory can be summarized that decisions to continue in activities, such as earning an engineering degree, are formed by beliefs in competency and value. While competency beliefs focus on a person's *ability* to do a task or engage in an activity, value beliefs focus on an individual's *desire* to engage in an activity or task.

A key retention construct associated with value beliefs is ***interest*** value, since interest is strongly linked to an individual's *desire* to continue pursuing engineering. Further studies related to the interest in engineering construct are summarized below. We hypothesize that enhanced student interest in engineering, generated by engineering-related experiences for first-year students, can counteract discouragement resulting from some gateway courses, making students more likely to persevere through these courses and persist in engineering. At our university, the platform for integrating specific engineering experiences is *Engineering Methods, Tools, and Practice II* (ENGR 111) [12-14], a first-year makerspace course that all first-year engineering students are required to take.

2. The Interest in Engineering Retention Construct

Various literature make the case that ***interest*** may be a construct within expectancy-value theory that can enhance student resilience in engineering. With a specific focus on engineering, the "interest in engineering" construct in this study can be defined as "student beliefs related to the significance and/or usefulness of engineering." This definition intrinsically includes student perception(s) related to the satisfaction level experienced in conducting engineering-related tasks or activities, and/or the level of pride associated with becoming a professional engineer.

2.1 Influence of Interest on Retention at Our University

There are numerous reasons why the authors have identified interest as potentially one of the most influential of expectancy-value constructs. A recent study at our institution identified interest as the primary barrier for students [15]. In that study, the magnitude of interest was found to be a critical predictor for first-year retention. In a 2011 study at our institution [16], first-year engineering students were instructed to respond to nine different factors (i.e. potential constructs) and rank the top three they considered when deciding on what career to pursue. The interest construct was the top selection by the highest percentage of students, and was present in the top three for the highest percentage of students. In 2016, another study at our university [17] focused exclusively on the effects of interest in engineering on first-year retention found that out of the top three factors influencing students' decisions to study engineering (interest in engineering, job availability, and good pay), interest in engineering was the only barrier specified as a reason students actually left the school of engineering. In addition, first-year students were categorized into a 2x2 matrix: first-year students with below-average versus above-average GPA, and first-year students with low versus high (mean-split) engineering interest. For students with above-average GPAs, there was a 27% increase in retention for those with high interest (versus low interest), while for students with below-average GPAs, there was a 40% increase in retention for students with high interest (versus low interest) in engineering.

2.2 Influence of Interest on Engineering Retention Nationwide

While the studies above focused on our university's students, the impact of the interest construct extends to engineering programs nationwide. Various studies show that engineering interest, significance, and usefulness are the most likely determinants of students' intentions [18-22]. A highly cited multi-institutional study [23] assessed why engineering students who had expected to be successful left the program. The top identified barrier was loss of interest in engineering. In the previously-referenced longitudinal study on engineering retention, Seymour and Hewitt identified the level of interest as "salient" to career preferences. Finally, an investigation at the University of Pittsburgh [24] additionally documented loss of interest in engineering as a major cause for leaving the engineering program.

2.3 Measurement of Interest Subdomains

Many theorists have historically separated the construct of interest into two separate domains: ***situational interest*** and ***individual interest***. Situational interest is immediate interest generated by a specific situation or *triggering* event and which has the potential to be impacted in a brief amount of time [25-28]. In contrast, individual interest is the type of long-term (i.e. *maintained*), more stable interest that tends to only be changed slowly over time [29-32], and is consequently more effective at positively influencing longer- term engineering student retention. This paper will be using the labels "maintained interest" for the long-term, stable interest construct, and "triggered interest" for the event-driven or situation-driven immediate development of interest. Some theoretical models suggest that triggered interest is critical in the development of maintained interest [25, 27-28, 33-35].

The longer-term research agenda of the authors includes a focus on studying the impact interest in engineering can have on student retention. One of the first steps in realizing this research agenda – and the main focus of this paper – is the necessity of identifying an appropriate measurement of engineering interest; more specifically in this study, *maintained* interest. For this paper, structural measurement model(s) intended to measure first-year engineering student interest in engineering were based on the work of Linnenbrink-Garcia et al [35]. In particular, during the Spring 2019 semester of ENGR 111, student perceptions in *maintained* interest were measured utilizing the 8-item maintained interest scale developed and tested in the Linnenbrink-Garcia article. Since the Linnebrink-Garcia study used middle and high school students and their interest in mathematics, the applicability of this particular measure for first-year engineering students requires further testing since as they stated, "…it will be important to continue to test the utility of these measures in other domains and age groups" (p. 667). Additionally, a report by Pintrich et al [36], which was the original source from which Linnenbrink-Garcia adapted, Pintrich characterized "task value" (which was relabeled "individual interest" by Linnenbrink-Garcia, followed by relabeling as "maintained interest" in this paper) as "judgements of how interesting, useful, and important the course content is to the student" (pg. 802).

The remainder of this paper will explore Pintrich's 3-part characterization of "task value" used to conceptualize and then test a 3-subfactor structure to the maintained interest student responses, when measured same way as Linnenbrink-Garcia did. Accordingly, the methodology, results, and discussion that follows will address the following research questions:

1. What is the strongest ***factor structure*** for measuring the construct of first-year engineering students' long-term, stable ***maintained interest*** in the choice of pursuing an engineering career?
2. How ***strong is the fit*** of theoretically-grounded ***structural models*** of the construct of first-year engineering students' maintained interest in engineering careers?

3. Methodology

3.1. Sample

All first-year engineering students at our university take a required introductory 2-course engineering sequence. The data collection was conducted in the second semester (Spring 2019) with the entire cohort in the second course, thus all engineering majors including 'undecided' were a part of the cohort sample which was invited to complete the survey. A total of 443 students in that first-year engineering cohort were administered the interest survey described in Table 1. Of those students, 424 (96% response rate) of the cohort returned completed surveys, and the subsequence data analyses are based on those 424 student responses.

3.2. Measures

To measure maintained interest, a 5-point Likert scale (from *completely true* to *not true at all*) was used, stemming from an 8-item maintained interest survey used and validated by Linnenbrink-Garcia and colleagues [35] in a study of middle and high school students. The item wordings were slightly modified to refer to engineering rather than mathematics as was done in that original study. See Table 1 for the wording of the survey items.

3.3. Analyses

Linnenbrink-Garcia and colleagues based their survey on Pintrick's [36] 3-part characterization of interest. We explored the potential factor structure of the construct of maintained interest by grounding our structural models based on three potential factors from Pintrick's (1993) characterization of interest: useful, important, enjoyable. Furthermore, the first two factors relate to pragmatic features of the engineering profession (useful, important) whereas the third factor targets an affective feature of engineering (enjoyable). Table 1 attaches one of each of these 3 factors to each of the specific items on the survey.

Table 1. Maintained Interest Survey Items and Hypothesized Factor Structure.

Item code	Item	Hypothesized Factor Structure	
use1	Engineering is practical for me to know.	useful	
use2	Engineering helps me in my daily life outside of school.	useful	pragmatic
imp1	It is important to me to be a person who reasons as an engineer.	important	

imp2	Thinking as an engineer is an important part of who I am.	important	
enj1	I enjoy the subject of Engineering.	enjoyable	affective
enj2	I like Engineering.	enjoyable	
enj3	I enjoy doing Engineering.	enjoyable	
enj4	Engineering is exciting to me.	enjoyable	

To investigate the factor structure of the construct of *maintained interest*, two structural equation models (SEM) will be built using both the 3-factor structure and the 2-factor structure that combines the first 4 survey items into one "pragmatic" feature of interest (see Table 1). A suite of fit indices which each approach the question of data fit to the model from a different perspective will be used to evaluate the fit of each model to the data in order to identify the strongest factor structure suggested by the data. The fit indices to be explored include: (1) the Goodness-of-Fit-Index (GFI) which represents the data fit to the model from a 'proportion of variance explained' perspective, with GFI>0.90 typically considered a reasonably good fit; (2) the Comparative Fit Index (CFI) which represents the data fit to the model by comparing the fit to a baseline model of no presumed structure, with CFI>0.90 typically considered a reasonably good fit; and (3) Root Mean Square Error of Approximation (RMSEA) including the 90% confidence interval, which represents the remaining normalized residuals in the data that the model doesn't explain, with RMSEA <0.10 often considered a reasonable fit for this index.

4. Results

First the 3-factor model for maintained interest was built, and fit indices computed – see Figure 1 for this structural model.

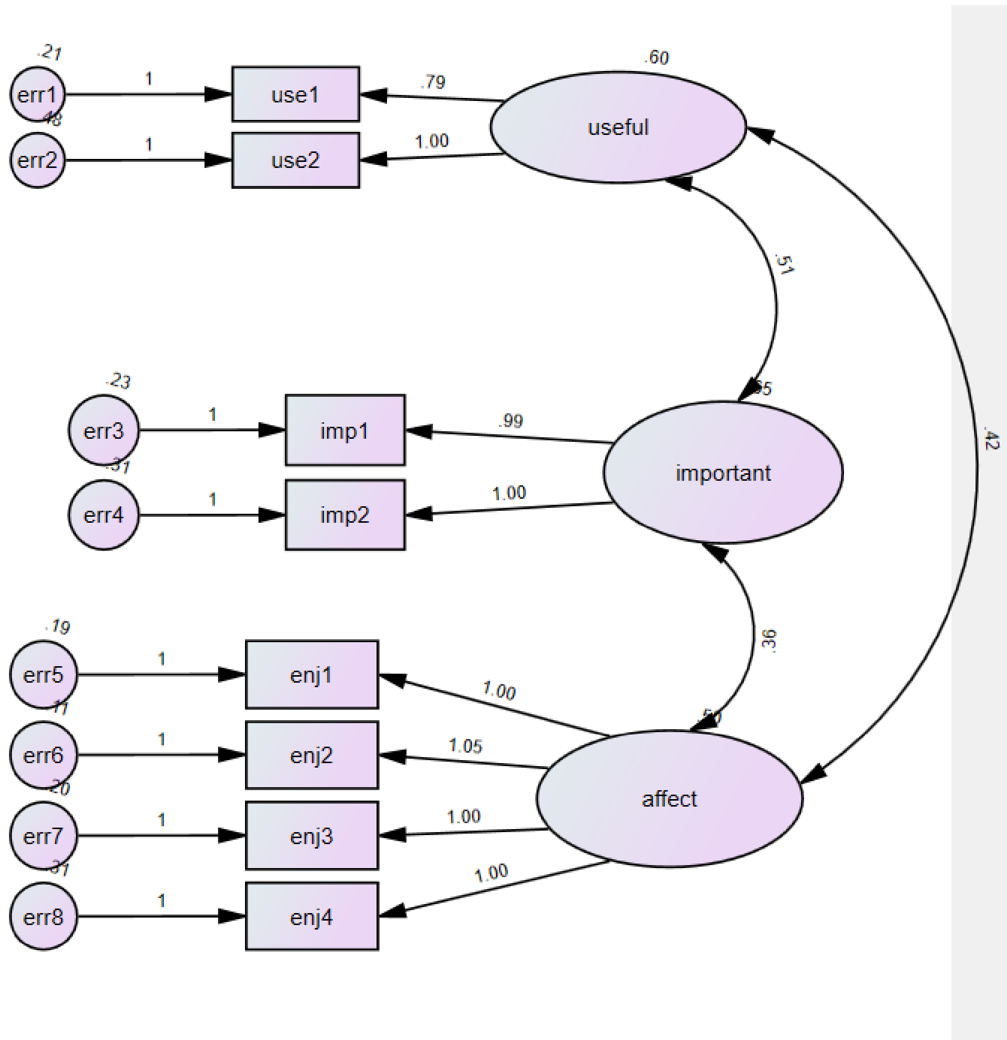

Figure 1. Three-Factor Measurement Model for Maintained Interest

The best-fit model regression weights, based on the sample of responses from the 424 first-year engineering students, are shown in Figure 1. Note that the oval shapes are used to represent the three latent factors embedded in *maintained interest* by this hypothesized model, with the rectangles representing the observable, measured items from the survey, and the residual measurement errors captured by the circles attached to the left of each observable measure. Table 2 reports the suite of fit indices of this 3-factor model.

To compare the fit of the hypothesized 3-factor model in Figure 1 to an alternate 2-factor model of *maintained interest*, the structural equation model in Figure 2 was built and the fit indices to the data computed.

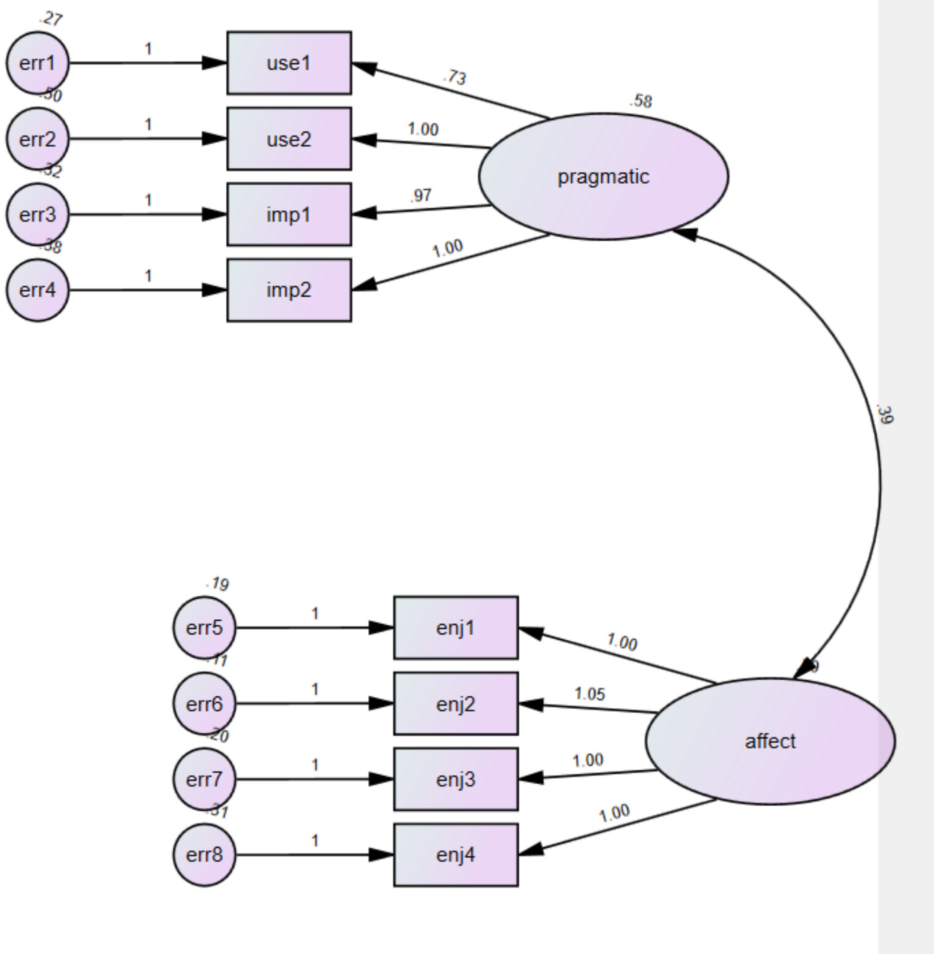

Figure 2. Two-Factor Measurement Model for Maintained Interest

As with Figure 1, the best-fit model regression weights, based on the sample of responses from the 424 first-year engineering students, are shown in Figure 2. Table 2 reports the suite of fit indices of this 3-factor model.

Table 2. Fit Indices Statistics for Comparing 3-Factor and 2-Factor Measurement Models

Model	GFI	CFI	RMSEA [90% CI]
3-Factor	0.945	0.963	0.107 [.087, .127]
2-Factor	0.912	0.939	0.129 [.110, .148]
Interpretation guide for good fit	>0.90	>0.90	<0.10

Note. GFI = goodness-of-fit index; CFI = comparative fit index; RMSEA [90% CI] = root mean square of approximation with 90% Confidence Interval

5. Discussion

5.1. Comparative Factor Structure

The suite of fit indices suggests that both the 3-factor maintained interest measurement model and the 2-factor measurement model attain reasonable fit with the GFI and the CFI, though the 3-factor model does present stronger fit for both of these indices. However, the residual error fit index suggests that the 3-factor model is a substantially better fit than the 2-factor model, with the point estimate of RMSEA for the 3-factor model approaching the general interpretation guideline of close to 0.10 as an indication of reasonable good fit, and when considering the 90% confidence interval for this index the desirable fit metric is included within this confidence interval. For the 2-factor model, not even the lower bound of the 90% confidence interval of RMSEA reaches the desired target value of 0.10, suggesting that the 2-factor model is not a sufficiently strong fit to our data to reasonably measure the maintained interest of these first-year engineering students.

These results suggests that a stronger measurement model for first-year engineering students' maintained interest in engineering would retain all three latent factors (see Table 1), since students tended to indicate meaningfully divergent response patterns to questions pertaining to the usefulness of engineering (items 1 and 2 in Table 1) as distinct from their judgement of the importance of engineering (items 3 and 4 in Table 1) in terms of influencing their interest in engineering. This outcome supports Pintrich's [36] assertion that students' interest in an academic field would be an amalgamation of "judgements of how [enjoyable], useful, and important the course content is to the student" (pg. 802).

5.2. Strength of Fit

Not only is the 3-factor model a stronger fit to the data across all fit indices when compared to the 2-factor model, but the strength of these metrics suggests that this is a reasonably well-fitting measurement model in an absolute sense. Thus, based on these results, there is empirical support for the appropriateness of using the 3-factor model captured in Table 1 to measure first-year engineering students' interest in the engineering profession as a career choice.

6. Future Directions

Building upon this established measure of maintained interest, the next step in our research agenda will be to use analogous methodology in measuring *triggered* interest. ENGR 111 course administrators are currently in the process of developing these triggered interest measures, targeting select engagement features of the ENGR 111 experience. Once an appropriate *triggered interest* measure is established, experimental plans are underway for studying how to bolster triggered interest by systematically modifying select features of the ENGR 111 experience. Additionally, another research objective will include studying how triggered interest evolves into lasting maintained interest.

Although triggered interest is expected to improve first-year engineering student retention, this retention can be short-lived if the environment does not continue to support student interest, while the longer-term stable maintained interest likely has a greater impact on longer term retention [35]. Even though maintained interest and triggered interest are theoretically distinct, some models suggest that triggered interest can eventually develop into maintained interest [e.g. 27-28]. For example, pedagogical (triggered) situations can promote maintained interest if they foster individual empowerment [27-28, 31, 33, 37-38]. The Linnenbrink-Garcia study [35] suggested triggered interest measured early in the school year predicted the change in maintained interest during the school year. The authors posit that once engineering students experience well-designed ENGR 111 course features, those who view the set of course experiences as enjoyable and/or meaningful are more likely to value their engagement as burgeoning engineers and perhaps seek out and/or look forward to additional opportunities to grow as engineers. In this way, triggered interest might be transformed into maintained interest. Therefore, it is critical to understand the connections between specific first-year engineering course experiences, subsequent triggered interest in engineering, and leading to longer-term maintained interest in engineering. Ultimately this series of first-year experiences may then lead to stronger patterns of engineering retention for our first-year students.

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