Measuring Predictors of Persistence: An Instrument for First-Year Engineering Students

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Abstract

This empirical research paper builds on a previous study [1] describing an NSF S-STEM project aimed at increasing engineering persistence and graduation among low-income, academically talented students through first-year initiatives. Grounded in Tinto's model of motivation and persistence, this paper illustrates an instrument to assess four predictors of persistence in undergraduate programs: intensity and clarity of goal to graduate, self-efficacy, sense of belonging, and perceptions of the curriculum [2]. Using confirmatory factor analysis (CFA), we evaluate the internal consistency, reliability and convergent validity evidence for an enhanced instrument and compare it to the prior version. This updated instrument was examined with a new dataset and better reflects the four predictors of persistence. The updated CFA model operationalizes Tinto's predictors through six factors: Curriculum Relevance, Academic Engineering Confidence, Sense of Belonging, Engineering Identity, Comfort with Professor, and Advanced Engineering Degree. Results indicate strong measurement performance for Curriculum Relevance and Academic Engineering Confidence, with Sense of Belonging also demonstrating good measurement performance. In contrast, added items did not improve convergent validity evidence for the factors Comfort with Professor, Engineering Identity, or Advanced Engineering Degree, with Comfort with Professor showing the largest decline in Average Variance Extracted. These findings identify which items and factors require further refinement and help strengthen future analyses that connect instrument scores to students' persistence outcomes.

Introduction

Engineering undergraduate programs are often positioned as pathways to high-demand careers and upward social mobility. However, persistence in engineering remains marked by enduring inequities, particularly for low-income students who may face external pressures that compete with academic demands [3, 4]. These pressures can limit students' ability to engage in the academic and social experiences that support persistence during the first year. Economically disadvantaged yet academically talented students balance part-time employment, family responsibilities, and financial uncertainty, which can limit their academic focus, constrain opportunities for social integration, and reduce goal clarity during the critical first year [5, 6]. This reality motivates the design and evaluation of early, structured supports intended to promote persistence in engineering.

This study is situated within a multi-year NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) project at a four-year institution in the Northeastern

United States [7]. Across cohorts, the project implements coordinated first-year interventions intended to increase persistence by reducing financial strain and strengthening academic and social integration. These interventions include scholarships, an Engineering Learning Community (ELC) that supports cohort-based learning and living, mentoring, personal and professional development seminars, and inclusive practices embedded in first-year engineering lab courses. In our previous paper [1], we framed these efforts as an integrated approach to supporting low-income, high-achieving engineering students through both direct financial support and structured opportunities to develop peer networks and faculty connections.

The project is grounded in Tinto's conceptual model of student motivation and persistence, which emphasizes that persistence is shaped by students' experiences of academic and social integration [2]. In our framework based on Tinto's model, we define the primary predictors to students' motivation to persist as (1) intensity and clarity of goal to graduate, (2) self-efficacy, (3) sense of belonging, and (4) perception of curriculum [1, 2, 7]. In the current measurement model, we operationalize 'perception of curriculum' using a new factor called Curriculum Relevance. Consistent with our earlier definition and definitions used in other papers, we conceptualize engineering persistence as an individual staying in an engineering major or completing an engineering degree [8]. Students who switch between engineering majors but remain within engineering are still considered to have persisted.

One ongoing challenge in persistence research is measurement. Even when programs provide many supports, measures with weak validity evidence make it difficult to tell what is actually changing for students. In a previous study occurring during the first year of this project, we created, and gathered validity evidence for a survey for first-year engineering students based on Tinto's framework. Our approach explicitly attempted to measure all the theorized contributors of Tinto's conceptual model for persistence (rather than a single predictor such as self-efficacy or belonging) within one instrument designed for first-year engineering students. While the findings were promising, several factors did not consistently meet desired benchmarks for internal consistency, or evidence of reliability and convergent validity, indicating a need to strengthen the instrument before using it for broader comparisons or outcome-linked analyses.

Building on the prior validity evidence, the purpose of this paper is to strengthen measurement of the predictors of persistence and evaluate whether the enhanced instrument provides improved validity evidence compared to the previous version. We refined the survey by adding targeted items intended to strengthen weaker factors and by introducing additional items to better capture perceived curriculum relevance, a dimension of persistence not fully captured in the original instrument and one that may emerge as an additional factor. The central research question guiding this study is:

RQ: *What validity evidence is there for our new enhanced instrument, and how does it compare to the previous instrument?*

Background

Conceptual Framework

This work is guided by Tinto's conceptual model of student motivation and persistence, which emphasizes persistence from the student perspective and links persistence to motivation and to academic and social integration experiences [2]. In this framework, motivation is supported by four contributors: intensity and clarity of goal to graduate, self-efficacy, sense of belonging, and perceptions of the curriculum as shown in Figure 1.

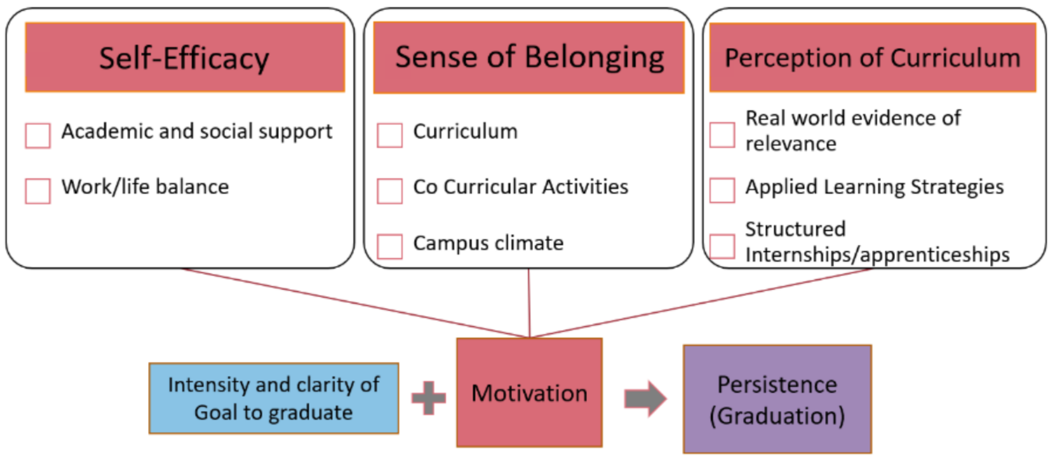

Figure 1: Tinto's model of motivation and persistence

Tinto's model further suggests that these predictors operate through students' academic and social integration, meaning that persistence is influenced not only by students' individual characteristics but also by how they experience the engineering learning environment. In the first year, integration can be shaped by classroom interactions, early performance feedback, access to support, relationships with faculty, and peer belonging. These experiences can strengthen or weaken students' motivation to continue in engineering by affecting their confidence, their sense that they belong in the discipline, and their perceptions of the value and relevance of the curriculum [2]. As a result, Tinto's framework is well-suited for evaluating first-year initiatives because it provides a theory-based pathway linking program supports to the persistence-related experiences students report.

Instrument development

To evaluate whether the interventions created in this project are influencing student experiences in theory-consistent ways, we developed a survey instrument designed specifically for first-year engineering students. Rather than focusing on a single predictor (e.g., sense of belonging), the instrument is intended to measure the broader set of predictors proposed by Tinto within a single tool that can be administered at scale in first-year courses.

In our previous study, factor analysis results suggested that the four theorized contributors could be represented by six interrelated factors as shown in Figure 2 [1]. However, the strength of validity evidence differed across factors. Some factors (e.g., Comfort with Professor and Engineering Identity) showed stronger performance, while others did not consistently meet benchmarks for evidence of internal consistency, reliability, and convergent validity (e.g., Advanced Engineering Degree and DEI Components) [1]. These results indicated that certain factors required refinement, either through improved item wording, additional items to better represent the factor domain, or revised factor structure. This had to be done before the instrument could be used confidently for cross-group comparisons or more advanced modeling.

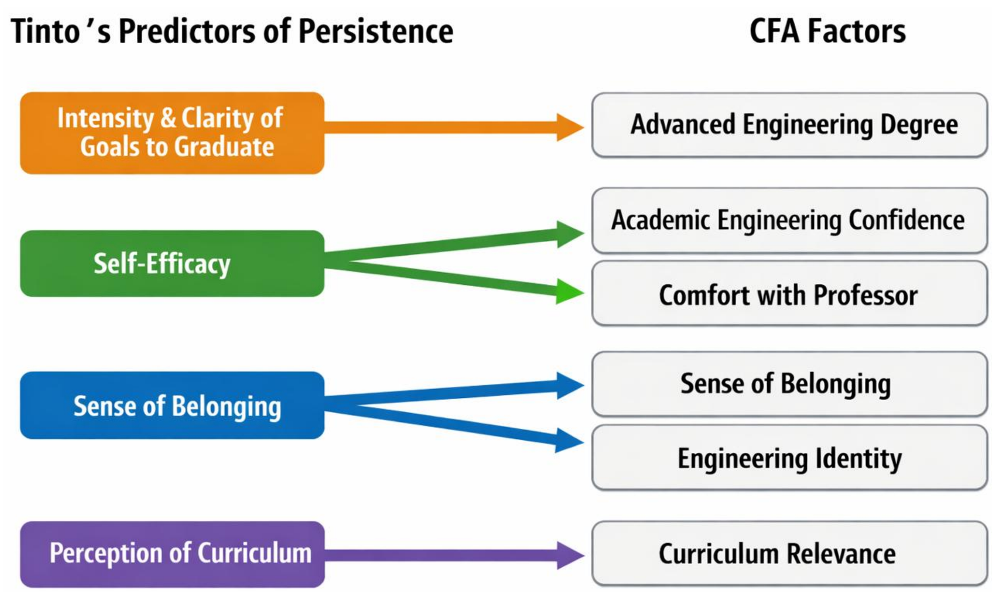

Figure 2: Subcomponents of Tinto's model of motivation and persistence

Study Design

This paper advances our prior validity evidence work through use of newly available data from a later survey time point. In the prior study, the measurement model was developed using Cohort 1 pre- and post-survey data for exploratory factor analysis (EFA) and then evaluated using Cohort 2 pre-survey data for confirmatory factor analysis (CFA). A key limitation at that time was that Cohort 2 post-survey responses were not yet available, so CFA and reliability evidence were limited to a single time point within Cohort 2. In the present study, Cohort 2 post-survey data collected at the end of students' first year is now available. This enables the CFA of the enhanced instrument using the same cohort previously used for CFA, but at a different time point and with an updated item set designed to improve measurement quality. This can be referenced in Figure 3 which compares our current study, Study 2 with our previous study, Study 1.

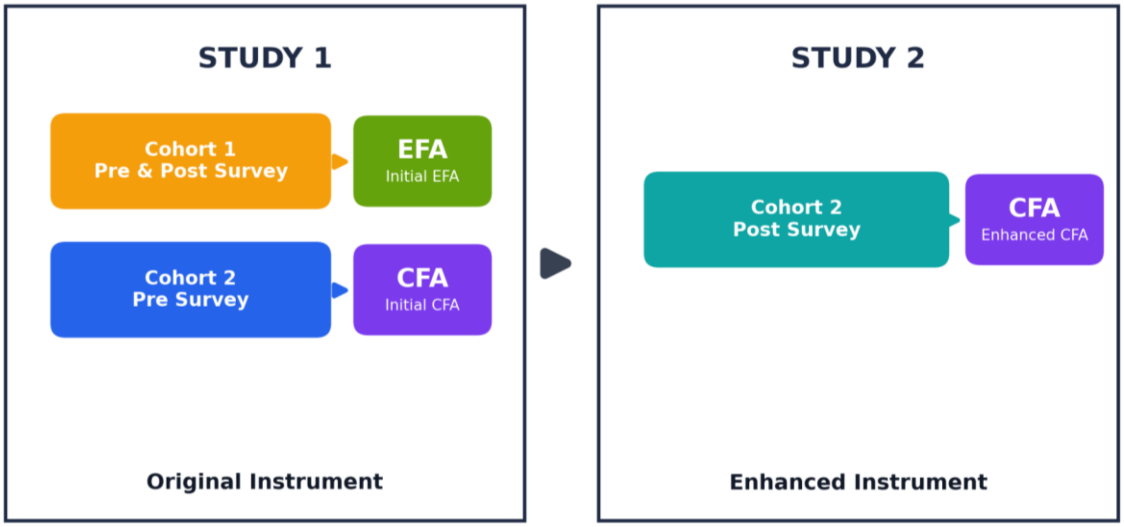

Figure 3: Comparing Study 1 with Study 2

Methods

Study context and participants

This study is part of a multi-year NSF S-STEM project at a four-year institution in the Northeastern United States. Surveys were administered in required first-year engineering courses at two time points each academic year: a pre-survey early in the academic year and a post-survey near the end of the academic year. Surveys were administered during students' required introduction to engineering course, and participation was voluntary.

This paper focuses on Cohort 2 post-survey responses, which were collected using the enhanced survey instrument. The Cohort 2 post-survey was administered to a population of approximately 380 eligible first-year engineering students, with a final sample of n=267 responses. The enhanced instrument included demographic items and n=40 key items used to construct the six CFA factors evaluated in this study.

Instrument Changes

The original instrument was designed to measure first-year experiences aligned with Tinto's model (e.g., self-efficacy, belonging, goals, and curriculum perceptions). In our prior work, factor analyses suggested that the four theorized contributors could be reflected through six interrelated factors: Comfort with Professor, Sense of Belonging, Engineering Identity, Advanced Engineering Degree, Academic Engineering Confidence, and Components for Diversity, Equity, and Inclusion (DEI) [1]. The DEI Components factor was later replaced with a new and improved factor, Curriculum Relevance, which aligns more closely with Tinto's proposed theory.

Results from the earlier analyses indicated uneven measurement strength across factors, motivating refinement of the instrument before broader comparative or outcome-linked analyses. In the enhanced instrument used in this study, items were added to strengthen weaker factors, and additional items were introduced to better capture curriculum relevance as a potential additional factor. The factor Comfort with Professor expanded from two items to six items. The factors Engineering Identity and Advanced Engineering Degree both expanded from three items to six items. Lastly, a new factor named Curriculum Relevance emerged with four items. These changes are reflected in Table 1 and resulted in the addition of fourteen new items to the enhanced survey.

Table 1: Item Changes

Factor	Original Instrument	Enhanced Instrument
Sense of Belonging	10 items	10 items (same 10)
Academic Engineering Confidence	8 items	8 items (same 8)
Engineering Identity	3 items	6 items (original 3 and 3 new items)
Comfort with Professor	2 items	6 items (original 2 and 4 new items)
Advanced Engineering Degree	3 items	6 items (original 3 and 3 new items)
Curriculum Relevance	Didn't Exist	4 items (4 new items)

Analytic Approach

Analyses were designed to address the research question: *What validity evidence is there for our new enhanced instrument, and how does it compare to the previous instrument?*

CFA was used to test whether the enhanced instrument demonstrates improved model fit and stronger metrics than the previous instrument. To better align with Tinto's "perceptions of the curriculum," the updated CFA model replaced the prior DEI Components factor with a Curriculum Relevance factor, which was evaluated alongside the remaining factors. Model evaluation relied on standard CFA fit indices, and factor loadings were examined to assess whether items were adequately associated with their intended factors. While the standard factor loading cutoff is 0.4, it was lowered to 0.3 to retain more items [9]. The EFA was rerun after each removal, improving communality scores. This process resulted in the deletion of ten out of thirty-nine survey items.

Internal consistency reliability was evaluated for each factor using Cronbach's Alpha and McDonald's Omega, reported alongside factor loadings and item performance to identify factors that may require further refinement. Convergent validity evidence was assessed using Average Variance Extracted (AVE) for each latent factor. Cronbach's α was used to estimate internal consistency, McDonald's ω to estimate composite reliability, and AVE to evaluate convergent validity evidence; together, these metrics summarize the measurement quality of the instrument [10]. Cronbach's α and McDonald's ω tells us the items are reliably related, while AVE tells us how clearly they measure one specific idea. For interpretation, α and ω values near or above 0.70

are typically considered acceptable reliability, while AVE values near or above 0.50 suggest stronger convergent validity evidence.

Results

The resulting CFA model included the following factors: Sense of Belonging, Academic Engineering Confidence, Engineering Identity, Comfort with Professor, Advanced Engineering Degree, and Curriculum Relevance.

Internal consistency reliability and convergent validity evidence were assessed using Cronbach's alpha (α), McDonald's omega (ω), and Average Variance Extracted (AVE) for each factor. Table 2 includes the internal consistency reliability and convergent validity evidence from the original instrument and Table 3 shows the internal consistency reliability and convergent validity evidence from the enhanced instrument used with Cohort's 2 post-survey.

Table 2: Original Instrument's Internal Consistency Reliability and Convergent Validity

Metrics	**Sense of Belonging**	**Academic Engineering Confidence**	**Engineering Identity**	**Comfort with Professor**	**Advanced Engineering Degree**	**DEI Components**
α	0.874	0.825	0.742	0.759	0.459	0.512
ω	0.875	0.831	0.744	0.765	0.454	0.550
AVE	0.417	0.389	0.494	**0.621**	0.233	0.312

Table 3: Enhanced Instrument's Internal Consistency Reliability and Convergent Validity

Metrics	**Sense of Belonging**	**Academic Engineering Confidence**	**Engineering Identity**	**Comfort with Professor**	**Advanced Engineering Degree**	**Curriculum Relevance**
α	0.833	0.856	0.744	0.731	0.597	0.861
ω	0.835	0.860	0.654	0.745	0.608	0.870
AVE	0.344	**0.473**	0.244	0.352	0.266	**0.632**

Overall, the enhanced instrument produced mixed results. Two factors carried forward without item revisions (Academic Engineering Confidence and Sense of Belonging), serving as a useful comparison point while other factors were modified. In contrast, the three factors targeted with added items (Comfort with Professor, Engineering Identity, and Advanced Engineering Degree) did not improve as expected across Cronbach's alpha, McDonald's omega, and AVE and, in most cases, demonstrated lower AVE values than the prior instrument.

Curriculum Relevance demonstrated the strongest overall measurement performance among the factors in the Cohort 2 post-survey CFA model. This result suggests that the added curriculum-focused items cohered well and aligned strongly with the intended latent factor. Importantly, this factor also represents an improved conceptual alignment with Tinto's "perception of curriculum" element compared to the prior DEI components factor, which was less directly tied to curriculum perceptions and had much weaker results.

Academic Engineering Confidence, which did not receive new items in the enhanced instrument, continued to demonstrate strong and stable measurement metrics. This factor remained one of the best-performing factors across both instrument versions, indicating that the original item set provided consistent measurement quality over time. Sense of Belonging also remained unchanged and showed metrics that were mostly similar to the prior instrument, indicating stability across iterations. Both Academic Engineering Confidence and Sense of Belonging could benefit from stronger AVE metrics, but their α and ω metrics performed very well (i.e., above 0.8).

Advanced Engineering Degree included additional items intended to strengthen measurement; however, results indicate very limited improvement. This pattern is consistent with earlier findings that this construct can be difficult to measure among first-year students, who may not yet have clearly formed intentions about graduate education [11]. Engineering Identity was expanded with additional items, but results suggest the factor performed slightly worse in this new model. This may indicate that the added items did not increase shared variance among indicators or may have broadened the factor in ways that reduced convergence. This result is notable because Engineering Identity approached the AVE threshold more closely in the prior instrument (AVE=0.494) [1].

The factor of Comfort with Professor was expanded the most since the last instrument, going from two survey items to six survey items. However, its convergent validity evidence weakened in the Cohort 2 post-survey model. This is a meaningful shift because Comfort with Professor previously demonstrated the strongest convergent validity evidence (AVE=0.621) [1]. The decreased AVE suggests that, despite additional items, the indicators may not be converging as strongly on a single latent construct in the updated model.

Discussion

This study evaluated the enhanced engineering persistence instrument using the Cohort 2 post-survey CFA and compared results to the prior instrument. Overall, findings were mixed: two factors were retained without item revisions, a new factor performed strongly, and several revised factors did not improve as expected.

A major change in the updated model was replacing the prior DEI components factor with Curriculum Relevance, which better aligns with Tinto's "perceptions of the curriculum." In the Cohort 2 post-survey CFA, Curriculum Relevance demonstrated the strongest overall measurement performance, supporting its inclusion as a core persistence-related construct for first-year engineering students.

The factors with added items, Comfort with Professor, Engineering Identity, and Advanced Engineering Degree did not strengthen in terms of convergent validity evidence, and Comfort with Professor showed the largest decline in AVE. One likely explanation is that the added items broadened these factors, reducing item convergence even if internal consistency remained acceptable. Together, these findings indicate that improving convergent validity evidence may require targeted revision and sharpening of item focus, rather than adding items alone.

Conclusion

This study evaluated the reliability and convergent validity evidence of an enhanced persistence instrument using the Cohort 2 post-survey CFA and compared the results to the previous instrument. The enhanced model retained moderate performance for Academic Engineering Confidence and Sense of Belonging, and it introduced Curriculum Relevance, which emerged as the strongest-performing factor and provides a clearer representation of Tinto's "perceptions of the curriculum." However, item additions did not improve convergent validity evidence for Comfort with Professor, Engineering Identity, or Advanced Engineering Degree, indicating that further refinement is still needed for these factors.

Guided by our research question, the enhanced instrument demonstrated strong reliability (**alpha/omega**), but convergent validity evidence results (AVE) were mixed across factors. This pattern suggests that several item sets were consistently related, yet some did not converge as strongly on a single underlying factor. Notably, the addition of Curriculum Relevance emerged as a clear strength of the revised model. Next, we will conduct item-level diagnostics (e.g., standardized loadings and each indicator's contribution to AVE) to identify newly added items that may be reducing convergence, revise or remove weaker indicators, and re-evaluate the refined measurement model in subsequent data collections, including future outcome-linked analyses supported by Cohort 3's paired and identified design.

Limitations

This study has several limitations. First, the data were collected at a single institution, which limits generalizability to other engineering programs with different student populations, course structures, or support initiatives. If implemented at other institutions, the instrument may require adaptation to fit local contexts and program designs.

Second, survey timing may influence responses. Post-surveys were administered near the end of the term, when students may be experiencing time pressure and fatigue, which can reduce response quality. A mid-semester administration could potentially provide additional insight, but scheduling constraints and course logistics make this difficult.

Third, although Cohort 2 provides paired pre–post responses, the primary focus of this paper is measurement quality (reliability and convergent validity evidence), not predictive validity evidence. As a result, the findings do not yet demonstrate how instrument scores relate to actual persistence outcomes (e.g., retention in engineering). Cohort 3 is designed to address this limitation through identified data collection and persistence tracking, but those analyses are not yet possible because the cohort is still in progress.

Finally, as with many survey-based studies, there are limits to verifying respondent engagement. While responses can be screened for missingness and extreme or patterned responding, the study cannot fully determine how many participants responded carefully versus providing rushed or inattentive answers.

Future Work

Future work will focus on continued refinement of the enhanced instrument, with particular attention to factors that did not improve in convergent validity evidence after item additions. Next steps will include item-level diagnostics to identify indicators that may be weakening convergence, followed by targeted revision or removal of problematic items and re-estimation of the CFA model. Another plan for the future of the project we have considered is to rework our persistence model by incorporating Alexander Astin's theory of involvement and John Bean's theory of student attrition [12]. This approach has been done in the past on research about student retention. This theory is newer than our current theory from Tinto's, but Tinto's theory has so much more support and research backing it up.

As Cohort 3 data collection is completed, the project will expand beyond internal reliability and convergent validity evidence to examine stronger forms of validity evidence. Because Cohort 3 is paired and identified, it will enable (1) linking survey scores to individual persistence outcomes (e.g., retention in engineering), (2) testing whether instrument factors predict persistence, and (3) evaluating how the experiences of first-year students change over time based on the six factors. In addition, once the measurement model is stable, future analyses will examine whether the instrument functions similarly across cohorts and different student subgroups.

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