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Comparing Implicit and Explicit measurements of Engineering and Research Science Identities in Engineering Doctoral Students

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Introduction

This research brief research paper investigates the relationship between implicit and explicit measures of engineering–research science identity in engineering doctoral students (EDS). Drawing on Social Identity Theory as deployed in engineering education research and integrating theoretical perspectives from social psychology, this research addresses the question: To what extent do EDS' implicit engineering–research science identities correlate with their explicit identities?

Engineering identity has been established as a relevant factor in student persistence and success [1], [2]. While existing research has developed explicit self-report measures of engineering identity [3], [4], [5], [6], social psychology research suggests these instruments may miss critical aspects of identity development [7], [8]. Of particular relevance is the concept of implicit self-concept—automatically activated self-evaluations or self-associations outside an individual's conscious awareness or control [9], [10], [11]. Recent studies in STEM education demonstrate that implicit measures can reveal identity conflicts not captured by traditional surveys [12]. While explicit measures can capture conscious self-perceptions, implicit measures are uniquely positioned to reveal internalized beliefs that may create tensions between students' engineering backgrounds and emerging researcher identities—tensions that could affect their integration into academic engineering communities and long-term career trajectories [13].

The transition from undergraduate to doctoral engineering education presents unique identity challenges that persist throughout graduate training [14], [15]. Even for students with strong undergraduate engineering identities, doctoral education requires developing new professional self-concepts as students transition from consumers to generators of engineering knowledge [16]. Recent empirical work demonstrates that EDS must integrate their emerging identity as a research scientist with their existing engineering identity while engaging in their new, multifaceted professional roles [17], [18]. This integration process necessitates drawing together engineering, science, and researcher identity frameworks because doctoral students simultaneously inhabit all these roles—they must maintain engineering competencies while developing scientific research skills and scholarly identities [6]. The process differs fundamentally from undergraduate experiences—while undergraduate frameworks focus on engineering practice and classroom activities [3], doctoral education often emphasizes research and academic preparation over traditional, industry-related engineering skillsets [19]. These shifts in professional emphasis during doctoral training create unique theoretical and measurement challenges for understanding identity development [4], [6], with implications for both student development and program outcomes [20]. Understanding how students navigate these identity transitions is crucial for supporting their development as future engineering researchers capable of entering the engineering workforce or pursuing academic careers [16].

Methods: survey

Data collection involved a three-part survey using the Qualtrics survey platform: 1) demographics, 2) explicit questions relating to identity, and 3) an implicit association test (IAT).

Demographic data collection encompassed both personal and academic characteristics. Personal demographic questions included opportunities for respondents to self-report race, gender, first-generation status, and unspecified minority identity. Academic demographic questions included year of study, program discipline, and undergraduate major discipline.

Explicit identity questions were modeled on the final survey questions of Perkins *et al.*[4]: engineering identity questions were unmodified, but questions relating to "science identity" and "research identity" were pooled or combined to create a single set of "research science identity" questions. This approach was motivated by the necessity to align with the IAT which can only probe a bias/preference between exactly two categories—identities in this instance—support for this modification is that previous quantitative work showed "the researcher and scientist identity tended to merge" [21].

An IAT requires two attribute categories and two target categories to which the attributes can be applied. Here, the IAT was deployed to measure implicit self-concept, thus the target categories were 'self' and 'other'; prompt words used were: *I, me, mine, my, myself* and *others, their, theirs, them, they*. The two attribute categories were: engineering (*build, design, iterate, implement, optimize*), and research science (*discovery, hypothesis, peer-review, phenomena, theory*). Pilot testing of these terms showed mean error rates below 10% and response latencies under 1000 ms, satisfying best practice recommendations [22]. IATgen's shiny webapp [23] built the IAT.

Methods: analysis

Responses from explicit survey questions were combined using loading factors reported by Perkins *et al.*[4]. Where questions relating to "scientist identity" and "researcher identity" were combined to probe "research scientist identity", the loading factors for each were combined as the mean, and also as the maximum (producing two separate estimates for each "research scientist identity" subconstruct). To compare measures from Perkins' instrument with the new explicit measures and the IAT scores, identity bias variables for each subconstruct were defined as the Engineering Identity strength less the Research, Science, or Research-Science Identity strength. For example:

$$[EI\text{–}SI]_{recognition} = [EI]_{recognition} - [SI]_{recognition}$$

Responses to the IATgen-generated timed-response questions were processed with the shiny analysis webapp hosted by IATgen [23] which calculates the standardized difference score (*D*-Score). This variable represents the difference in speed between matching attributes to targets in different pairings. Data were exported from IATgen, recombined with explicit survey data and regression analyses were done with an in-house python script. First, the degree of correlation between *D*-scores and various explicit measurements were determined. Second, select explicit scores were regressed onto the same scale as the IAT (unity slope, zero intercept). Third, two multiple linear regressions were performed: one using all three EI–RSI subconstructs (denoted MLR–3), one using just the recognition and performance subconstructs (denoted MLR–2), and one 3-regressor ridge regression was performed along with bootstrapping for ridge regression coefficient p-values.

Next, differences between the mapped explicit identity strengths and implicit D-scores were calculated for $EI\text{–}RSI_{recognition}$, and $EI\text{–}RSI_{MLR-3}$ to record each individual's explicit-implicit discrepancy. Additionally, to capture each individual's degree of over-reporting, the following variable was calculated:

$$EI\text{–}RSI_{over-rep} = |EI\text{–}RSI| - |Dscore|.$$

Finally, differences linked to demographic categories were explored using ANOVAs.

Results

Twenty-seven EDS completed the Qualtrics survey; none had missing data. One of the responses to the IAT did not meet recommended thresholds for suitable analysis (maximum time-outs, no excessive response speeds) [23] and was thus excluded. Demographic breakdown of the remaining 26 respondents are given in Table 1. Participants are not statistically unrepresentative of the EDS body at the institution except for a low-participation rate from Asian EDS.

Table 1: Demographics of survey respondents. Self-reported race was a two-part optional question—first asking to select any number of race identifiers, second asking for Hispanic/Latinx identification.

Demographic Category	Response	Count (%)
Gender	Female	11 (46)
	Male	13 (54)
	Transgender OR non-conforming OR prefer not to say	0 (0)
First-generation college student	Yes	4 (16)
	No	21 (84)
Race	White/Caucasian; not Hispanic	11 (44)
	White/Caucasian; Hispanic	5 (20)
	Asian	4 (16)
	Other OR multiple	5 (20)

Correlations between different measures of identity strength and identity bias are reported in Figure 1. In general, EI constructs were anticorrelated with SI and RI constructs whilst SI and RI constructs were correlated. The Research-Science/tist (RSI) measures for *recognition*, *performance*, and *interest* correlated strongly (r>0.9) with Perkins' separate measures (both SI and RI). Further, *recognition* measurements from Perkins' SI and RI were also both highly correlated (r>0.999) and significant. The strongest correlation with the implicit D-score is with the derived term $[EI\text{–}RSI]_{recognition}$: R^2=0.833, $p<1\text{x}10^{-10}$.

Multiple linear regression with three regressors showed significance (with Bonferroni-corrected alpha) for *recognition* and *performance* constructs, but not *interest*—likely due to collinearity of these variables (Variance Inflation Factor for $EI\text{–}RSI_{interest}$ was 3.56). A two-regressor model maintained significance for *recognition* while *performance* became non-significant. Ridge regression (α=1.0) achieved cross-validated R^2=0.644, with an intercept of 0.041. Results of the ridge regression are shown in Figures 2 & 3. A bootstrapping analysis determined that coefficients for *recognition* and *performance* were highly significant, while *interest* was not (p=0.036).

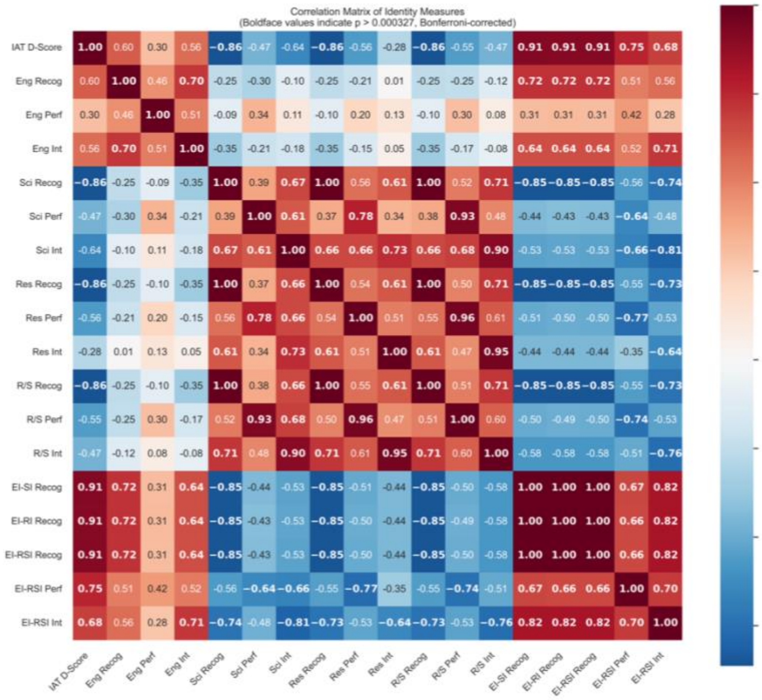

Figure 1: Correlations between different measures of identity. Numbers are correlation coefficients (*r*). Parentheses indicate non-significant *p*-values (*p*>0.000327).

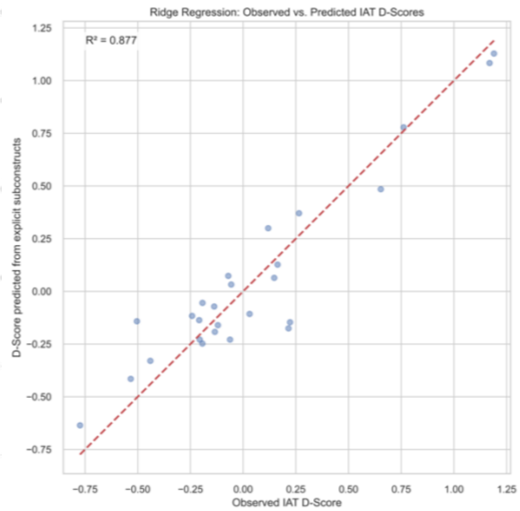

Figure 2: Scatter plot displaying observed versus predicted IAT *D*-Scores, with predictions based on three explicit identity subconstruct biases. Dashed red line represents perfect prediction. R^2 = 0.877, indicating explicit measures strongly align with implicit measures.

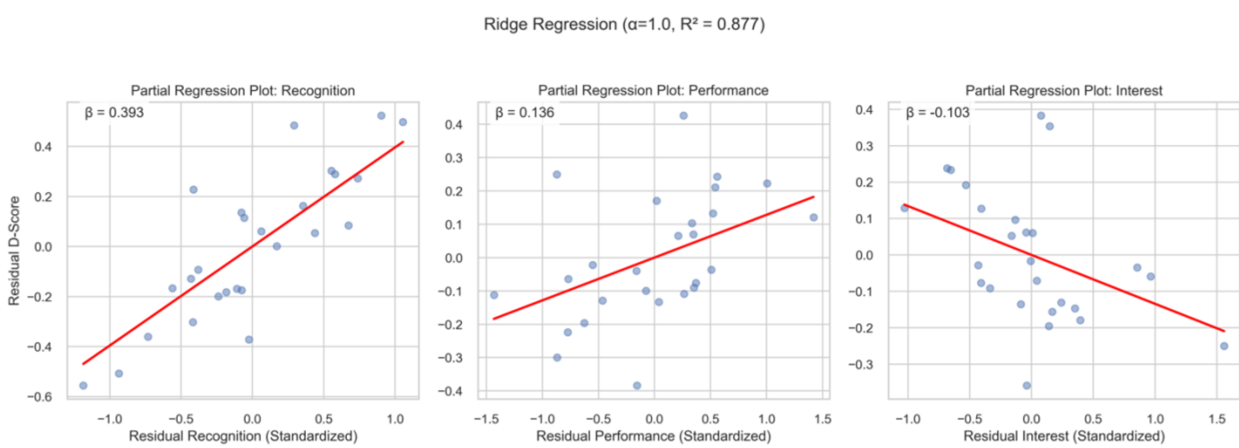

Figure 3: Partial regression plots for 3-factor ridge regression onto IAT *D*-score of EI–RSI differences for recognition, performance, and interest subconstructs. Optimal regularization strength α = 1.0. R^2 = 0.877

ANOVAs examining demographic differences showed gender emerged as a significant predictor of engineering identity. Women scored lower than men by approximately 0.41 points on both mapped engineering identity recognition scores ($F(1,20) = 4.73$, $p = 0.0418$, partial $\eta^2 = 0.159$) and *D*-scores ($F(1,20) = 5.03$, $p = 0.0365$, partial $\eta^2 = 0.165$). Race and first-generation status showed no significant effects on engineering identity measures.

Analysis of over-reporting indicated potential gender differences, with male participants showing larger gaps between explicit and implicit identity measures, though these effects did not reach significance ($F(1,20) = 2.09$, $p = 0.1635$, partial $\eta^2 = 0.082$).

Discussion

The sample population was validated through comparison with previous work. When explicit identity measures were compared using Welch's *t*-test with Bonferroni correction, no statistical differences were found between current participants' scores and those reported by Bahnson *et al.* [24] across Engineering Identity, Science Identity, and Researcher Identity measures, as well as all three subconstructs of Engineering Identity. This alignment suggests the current sample is representative of the broader engineering doctoral student population.

The combination of Science and Research identities into a single Research-Science/tist construct was supported by the data. High correlations ($r>0.9$) were observed between Perkins *et al.*'s Science, and Research Identity measures and the Research-Science/tist Identity measures here. Recognition measurements between all three identities were particularly strongly correlated ($r>0.999$), suggesting these constructs largely measure the same (or very similar) underlying identity component(s) in engineering doctoral students.

The relative contribution of identity subconstructs to overall identity strength was examined through ridge regression against implicit association scores. This approach differs from previous work with this instrument [24] where recognition, performance, and interest were weighted equally in identity calculations. The regression revealed recognition as the dominant predictor, with performance contributing moderately and interest showing a negative, but small and non-significant, association.

These findings contrast with previous work by Choe & Borrego [6] examining engineering identity in graduate students. There, interest emerged as the strongest predictor ($\beta = 0.474$) of engineering identity, followed by recognition ($\beta = 0.301$) and competence ($\beta = 0.118$). The different relative importance of these factors between explicit and implicit measures suggests the relationship between identity subconstructs may depend on measurement approach. Where Choe's study relied on explicit self-report for both predictor [6] and outcome [25] variables, the work here used implicit self-concept as the outcome measure.

Neither approach can be considered definitive for measuring identity strength. Explicit self-report measures may be influenced by social desirability bias or limited self-awareness, while implicit measures like the IAT may capture automatic associations that don't fully reflect consciously held identities. The contrasting results suggest each method may reveal different aspects of professional identity development. The negative loading of interest against implicit measures may indicate that doctoral students maintain different patterns of conscious interests versus unconscious self-associations as they navigate multiple professional roles.

The emergence of recognition as the dominant predictor in ridge regression analysis points to a central role in identity formation. Recognition from peers, faculty, and the broader academic community appears to shape implicit professional identity more strongly than performance or interest factors. This finding extends previous work on the importance of recognition in undergraduate engineering identity development to the doctoral context, where professional recognition takes on new dimensions through research contributions and academic engagement.

Gender differences in identity measurement showed significant discrepancies between explicit and implicit measures (partial $\eta^2 = 0.220$–0.248). Male students' tendency to over-report their stronger identity [29] aligns with broader patterns of confidence expression in engineering education [26], [27], [28], while female students' under-reporting of strong identity components may reflect internalized barriers or socialization patterns as seen with other identity fields [29], [30], [31].

The broad similarity between engineering and research science identities which are not true 'opposites' poses challenges for implicit measurement. Unlike traditional IAT applications that contrast distinct categories, these professional identities share characteristics and can both carry positive associations. The strong correlations between implicit and explicit measures despite these challenges suggests the robustness of both measurement approaches.

Technical aspects of the IAT implementation also merit consideration. While performance metrics met established standards, the choice of stimulus words for engineering versus research science categories required balancing distinctiveness with ecological validity. The selected terms achieved marginally acceptable error rates and acceptable response latencies, indicating participants could consistently distinguish between categories despite their overlapping nature but not flawlessly.

Sample size limitations affect the interpretation of these findings, particularly for demographic analyses. The underrepresentation of Asian students relative to the institution's engineering doctoral population may impact generalizability. However, the detection of significant effects and consistent patterns across multiple measures suggests underlying phenomena worthy of further investigation with larger samples.

Conclusions and Future Directions

The IAT implementation for Engineering versus Research Science identity complements existing explicit identity instruments by measuring automatic associations rather than conscious self-reporting. While the IAT cannot determine absolute identity strength, it reveals systematic differences between implicit associations and explicit self-reports. This approach helps distinguish genuine identity differences from reporting artifacts that appear as unexplained measurement variance.

Future work should continue with larger samples to validate gender-based reporting patterns, investigate disciplinary variations in identity development, and explore interventions to support identity integration during doctoral training. Longitudinal studies could track identity development over time, whilst other comparisons could include perceptions of the EI–RSI balance of EDS own research activities, of their group's research activities in aggregate, and of the profession identity of their PI.

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