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DUAL PERSPECTIVE STUDY OF GRIT AND ENGINEERING MINDSET USING PSYCHOMETRIC MODELS

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Abstract
This paper describes a twofold psychometric study on the impact of grit and engineering mindset on the academic achievement of undergraduate engineering students. Grit, explicitly the perseverance and passion for a defined long–term goal, and the engineering mindset encompassing an iterative and failure-tolerant approach to problem-solving, are both vital yet underexplored domains within the field of engineering education. With the application of recognized instruments, ranging from the Short Grit Scale (Grit-S) to the Engineering Mindset Inventory (EMI) to the application of SEM and IRT, the study aimed to examine the constructs' dimensionality, relationships, and predictive value.
Within the scope of this study, data from 180 students in various engineering disciplines were compiled and examined for consistency, structure, and performance at the item level. SEM results showed a notable positive correlation of grit and the engineering mindset, suggesting the constructs bolster one another in the enhancement of student engagement, resilience, and performance. IRT also identified high-informative items, particularly those related to grit. Group comparison analysis revealed shift variation and gender differences, but little variation between disciplines, suggesting broad relevance of the constructs.
The results are significant from an educational perspective; they suggest that grit and mindset should be developed in conjunction with one's technical skills and competencies to ensure comprehensive and balanced growth as a learner. Reflective evaluations and iterative design challenges along with failure-positive feedback systems can enhance these learner traits. This study offers a valuable contribution by affirming the interplay between cognitive grit and mindset fluidity as a significant foundation for developing resilient and innovative, as well as self-reflective engineering practitioners trained to tackle multifaceted problems of the 21st century.
Keywords: Grit, Engineering Mindset, Psychometric Models, Structural Equation Modeling, Assessment in Education, Resilience, Iterative Thought Processes

1. INTRODUCTION

The ever-changing and technological-reliant economy demands new methods and innovative approaches to education [1][13]. In the realm of engineering education, two psychological attributes have been noted to aid in mastering intricate and unpredictable multi-layered challenges: grit—defined as the engineering mindset. both attributes have been noted to foster perseverance and passionate commitment towards long-term goals [11]. Achievement gaps among students have been attributed to the absence of one or both psychological traits. Though, the combination of the two—they are known as grit and engineering mindset—has yet to be the center of comprehensive research [6].
This study aims to perform a bi-focal psychometric analysis of these constructs in order to study the relationship between the two and how their reciprocal influence manifests in students' learning outcomes.Using validated instruments and SEM and IRT based statistical modeling techniques, this research aims to elucidate the cognitive and motivational factors of engineering learners rigorously. This paper in a comparison perspective aims to show the role of grit in complementing engineering mindset attributes of experimentation, design under constraint, and tolerance of failure. In addition, the paper seeks to inform educational strategies that evaluate and foster appropriate knowledge alongside grit and mindset that would be required for engineering problems of the 21st century [3][14].
This is the first introduction that has been provided in engineering education that aims at delving deeper into two prominent psychological dimensions in the context of engineering education [12][15]. It describes the issue of research, presents appropriate contextual variables, and justifies the need to construct a psychometric model that captures latent variables which conventional scholarly metrics would not quantify.

1.1 Background and Rationale

Academic learning within the engineering field requires personal character features that extend well beyond the technical skills of a learner [4]. Features such as grit and the engineering mindset allow students to navigate through complexity, uncertainty, and failure which are common in engineering. Unfortunately, much of the academic assessments within engineering focus on intellectual features, neglecting the character attributes that would promote enduring success [8]. This study aims to combine grit and engineering mindset and study their relationships to develop more accurate quantitative models to deepen understanding of learner profiles. Uncovering the interplay between grit and the engineering mindset enhances focus on adaptive resilience, leading to significant shifts in educative patterns tailored to enable the development of both adaptive and resilient failure among engineering learners [10].

1.2 Objectives of the Study

This study investigates the combined influence of grit and engineering mindset on the academic persistence and problem-solving ability of engineering students. Specifically, the study attempts (1) to establish the psychometric reliability of the grit and mindset scales on the students, (2) to assess the relationship between grit and engineering mindset, and (3) to evaluate the extent to which these constructs are able to perform across educational and demographic groups [7]. Using SEM and IRT, the study seeks to examine latent constructs which often go unnoticed by conventional performance indicators. Ultimately, it seeks to provide guidable information to faculty, curriculum developers, and engineering-specific learning support personnel, for fostering learner resilience in engineering.

1.3 Research Questions and Hypotheses

This investigation is framed around three key research questions: (1) How reliable are the grit and engineering mindset scales from a psychometric perspective for engineering undergraduates? (2) What is the model of structural relations for grit and engineering mindset? (3) How do these traits, individually and in combination, predict various academic outcomes for differing student profiles? From these questions, the following hypotheses are posited: H1: Grit and engineering mindset are positively correlated; H2: Greater grit is expected to enable a higher adaptability of engineering mindset; H3: Both traits have a joint effect in academic attainment. Testing these through psychometric modeling would aid in understanding the extent to which character traits can complement cognitive metrics in engineering education [5] [9].

2. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

A properly synthesized literature review clarifies how the psychological constructs of grit and the engineering mindset have both stood apart and intermeshed to shape learner trajectories in STEM contexts. Duckworth's popular operationalization of grit—perseverance and passion directed toward long-term objectives—now correlates consistently with academic indices including GPA, task continuation, and lower attrition. Concurrently, the engineering mindset—anchored in iterative experimentation, resilience in the face of setbacks, and a design-centric orientation—has been prioritized in engineering curriculum reform. Despite this convergence, existing investigations rarely examine how grit and engineering mindset cohabit, bolster, or substitute for one another in rigorous academic domains.

To address the gap, this section proceeds through three focal domains: measurement and validation of grit in classroom contexts, cultivation and evaluation of the engineering mindset in technical learners, and the application of advanced psychometric modeling to isolate and validate latent psychological variables. Using these lenses, the review uncovers an imbalanced literature where constructs are often examined in functional silos, overlooking potential synergistic interactions.Some evidence indicates that grit-laden learners gradually acquire engineering mindset characteristics, while other investigations observe that immersion in structured problem-based pedagogies may advance both profiles concurrently.

Leveraging psychological and educational paradigms, this review formulates a psychometric model designed to assess grit and engineering mindset not as discrete variables but as mutually reinforcing constructs. Operating from this hybrid vantage point is essential for elucidating the comprehensive range of learning trajectories and for informing the development of strategically targeted interventions within engineering curricula.

2.1 Grit and Academic Persistence in Engineering Education

Grit has been empirically associated with sustained academic engagement among engineering undergraduates confronted with the rigors of capstone-design courses and arduous sequenced curricula. Distinct from cognitive ability or standardized metrics, grit captures the capacity for prolonged, purpose-driven effort in the face of adversity. Engineering practice frequently subjects students to iterative failure, yet individuals scoring high on grit inventories are statistically more likely to redouble effort, reformulate strategies, and, crucially, sustain domain-specific interest across multiple semesters. Quantitative evidence correlates elevated grit with improved persistence-to-graduation, enhanced calibration of study intensity, and prolonged cognitive engagement on complex, open-ended tasks. Nevertheless, the micro-processes by which grit translates into superior engineering problem-solving remain insufficiently explicated, indicating a need for longitudinal, multilevel psychometric modeling to delineate causal pathways and inform pedagogical interventions.

2.2 Defining and Measuring the Engineering Mindset

The engineering mindset is characterized by an individual's capacity to navigate uncertainty, refine solutions through cyclic testing, and recalibrate designs in response to partial failures. This mindset is associated, albeit loosely, with competencies such as systems-level reasoning, prototypical experimentation, and interdisciplinary teamwork. Unlike conventional academic outcomes, the engineering mindset prioritizes epistemological stance and procedural disposition over factual retention. Consequently, evaluation has transcended simple quantitative proxies for stamina—portfolio documentation, rubric-based judgments, and formative reflection have constituted the prevailing metrics. Nevertheless, more recent work is developing assessment processes aimed at reifying and standardizing measurement which employs rigorous test theory. A more detailed look at the conceptual and empirical connections between grit and the engineering mindset could enhance our understanding of learner resilience and help shape more refined and flexible instructional designs.

3. RESEARCH METHODOLOGY

The study uses a cross-sectional approach within a single time frame to understand quantitatively the relationship between grit and the engineering mindset in diverse cohorts of undergraduate engineering students, which is informed by psychometric modeling. A latent trait is measured with a bounded slider by the structured questionnaire which consists of the Grit-S metric and the Engineering Mindset Inventory (EMI). SEM and IRT are used in the analytical phase. This permits both confirmatory and exploratory evaluations of interrelated psychological constructs within a single framework. The study's participants were purposively sampled from two engineering schools, which were selected to provide diversity with respect to academic level, concentration within the discipline, and trajectory of academic performance. Criteria for inclusion required prior exposure to a project-based curriculum due to the presumed simultaneous development of grit and mindset in that setting. All participants were ethically cleared by institutional review boards and gave informed consent at the time of recruitment.

Data were collected through a dedicated institutional account to which the participants were given secure access to answer the survey, upon which the dataset was subjected to preprocessing for missing answers, answer fabrication, and multicollinearity.Descriptive statistics first yielded demographic distribution, and structural equation modeling subsequently examined the proposed linkage between grit and engineering mindset. Item response theory additionally ascertained the difficulty and discrimination parameters of scale items, stratified by demographic subgroups. This triangulated analytic framework fortifies the interpretability of psychological dimensions and signals constructively relevant levers for pedagogical intervention.

The methodology integrates psychometric precision with educational relevance. Focusing on internal construct validity within the explanation of structural relationships among dispositional factors seeks to produce knowledge that is deeply interpretive yet broadly applicable to engineering teaching, student modeling, and intentional curriculum design.

3.1 Sample Selection and Participant Profile

The study recruited 180 undergraduate engineering students, from two accredited institutions, covering the disciplines of mechanical, electrical, and computer engineering. The group consisted of first to final year students, between the ages of 18 and 24, who had previously participated in at least one experiential, design-centered learning unit. Stratified sampling considering gender balance, academic standing, and GPA quartile was done to increase statistical generalizability. After being briefed on ethical measures, subjects provided informed, volunteer consent and completed the study online in accordance with each campus's human subjects' regulations. The resulting heterogeneity allows for the examination of grit and growth mindset in relation to academic progression and the level of structured learning.

3.2 Psychometric Instruments Used

The instruments used for this study included the Short Grit Scale (Grit-S) and a modified version of the Engineering Mindset Inventory (EMI). Grit-S consists of eight items that can be divided into two subscales: consistency of interest and perseverance of effort. The revised EMI includes twelve items that measure adaptive problem solving, failure tolerance, and commitment to frequent, incremental learning. Each scale uses a 5-point Likert scale as its anchoring response format. Internal consistency was measured through Cronbach's alpha, and construct validity was assessed through Confirmatory Factor Analysis (CFA). The combination of the instruments provides a comprehensive description of the cognitive and motivational factors that drive success in the engineering curricula which later allows for the application of Structural Equation Modeling (SEM) and Item Response Theory (IRT).

4. STATISTICAL ANALYSIS AND MODEL DESIGN

The analytic method used for this study applies intertwining psychometric modeling approaches to spatially clarify the latent relationship between grit and the engineering mindset. SEM was used to evaluate causal origination and reciprocal influence between the two constructs and provided IRT-length insights regarding the differential rate of item-level response guiding on underlying grit and engineering mindset levels. The SEM analysis explored a preset model where grit and the engineering mindset are defined as latent mutually reinforcing variables that together influence student engagement and, afterward, academic achievement. Comprehensively evaluating model adequacy was captured within the standardized aggregate conventional criteria of fit including CFI, TLI, RMSEA, and SRMR.

Exploratory Factor Analysis (EFA) defined the scale's dimensions prior to Structural Equation Modeling (SEM), and this first estimate revealed the latent traits that were potentially important. Confirmatory Factor Analysis (CFA) then validated the factor structure, confirming the extension of the engineering mindset instrument—subserving several grounded subscales—as confirming the engineering mindset construct's coherence. As part of the refinement, parallel analysis combined with eigenvalue graphics to refine dimensionality. The resulting path coefficients clarified distinct components of grit such as perseverance of effort as well as engineering mindset attributes like resilience in the face of failure. Using the graded response model, IRT was applied to measure item difficulty and discrimination for both metrics. With this approach, more granular analyses of item performance were possible, including analysis by gender, cohort, and academic standing. Subsequently DIF analysis was applied to test whether the items are performed without bias across the defined demographic groups. The combination of SEM and IRT gives a richly detailed explanatory model for intertwining educational processes and psychological concepts. Altogether, the analyses strengthen construct validity by intertwining trait and item perspectives, thus revealing the relationship between grit and the engineering mindset in engineering education.

4.1 Exploratory and Confirmatory Factor Analysis (EFA/CFA)

An exploratory factor analysis was done on the grit items as well as on the engineering mindset items to clarify their latent structures, followed by a confirmatory factor analysis to assess the coherence of the dimensions within each construct. The grit indicators were shown to cluster into two discrete factors of, "perseverance of effort," and "consistency of interest." The engineering mindset indicators, on the other hand, clustered into three factors which were: "design iteration," "tolerance of failure," and "systems thinking." Evaluation of model fit included RMSEA, CFI, and SRMR metrics, which were RMSEA < 0.08, CFI > 0.90, and SRMR < 0.08, all yielding satisfactory fit.The integrative two-phase analysis substantiates that each measurement scale consistently captures its proposed theoretical domain, thereby legitimizing their deployment in augmented structural modeling of learner-related behaviors within engineering education settings.

4.2 Structural Equation Modeling (SEM) Pathways

Structural equation modeling assessed the conditional linkages among grit, an engineering mindset, and observed performance indicators in student cohorts. A bifactor latent construct model was specified, positioning grit and mindset as antecedents influencing scholastic resilience and project-oriented learning achievement, both self-reported. Standardized path estimates indicated robust positive links between perseverance and capacity for design iteration, underscoring the tendency of more grittily-oriented learners to exhibit stamina during cyclic engineering challenges. Collectively, the latent system accounted for 42 percent of variance in success metrics. The SEM framework allowed for nuanced examination of motivational-cognitive interactions and yielded a robust measurement platform capable of guiding empirically calibrated pedagogical interventions.

5. RESULTS AND INTERPRETATION

The investigation offered important evidence on the interplay between grit and the engineering mindset and their collective impact on engineering students' academic performance. Confirmatory Factor Analysis confirmed the grit construct as composed of perseverance of effort and consistency of interest, while the engineering mindset comprised design iteration, failure tolerance, and systems thinking. All latent variables exhibited strong reliability (Cronbach's alpha exceeding 0.80) and robust goodness-of-fit statistics (CFI = 0.93, RMSEA = 0.06), confirming the appropriateness of the measurement framework.

Subsequent Structural Equation Modeling indicated that grit was a significant and positive precursor to the engineering mindset, specifically influencing durability in the face of difficulty and openness to failure ($\beta = 0.61$, $p < 0.001$). Both grit and engineering mindset correlated with more favorable academic performance markers, including self-assessed effectiveness in project work, the quality of peer collaborations, and sustained effort during complex problem-solving. The integrated model accounted for 47% of the variance in academic resilience and 39% in confidence during problem-solving tasks, suggesting that the synergy of these characteristics meaningfully informs learner success.

Item Response Theory analysis identified that mindset questions emphasizing adaptive design cycles and grit questions focusing on sustained long-term attention provided the highest discrimination across the performance quartiles. Differential Item Functioning analysis identified negligible, item-level variations in response patterns across genders for a limited subset of questions; these items will receive targeted revision in forthcoming assessments.

Qualitative open-ended responses provided additional, non-numeric evidence reinforcing the quantitative patterns. Students with elevated scores on both grit and mindset measures elaborated on experiences of intensive immersion in design tasks and cited a readiness to iterate and continue despite setbacks. These consistent patterns support the contention that grit and engineering mindset jointly foster the psychological disposition necessary for sustained engineering problem-solving.

5.1 Reliability and Validity of Instruments

Reliability analyses confirmed robust internal consistency for both the grit scale ($\alpha = 0.83$) and the engineering mindset scale ($\alpha = 0.87$). Factor loadings for each item surpassed the 0.60 criterion, substantiating convergent validity.

Discriminant validity was verified, as the average variance extracted (AVE) for each construct exceeded the 0.50 benchmark. Confirmatory factor analysis corroborated the hypothesized multidimensional structure, yielding satisfactory fit indices (CFI = 0.93, RMSEA = 0.06). Taken together, these indices affirm that the measurement instruments employed in the present study possess the necessary psychometric robustness for precisely capturing the intended traits among engineering undergraduates.

5.2 Relationship Between Grit and Engineering Mindset

Structural equation modeling outcomes corroborated a substantial and statistically significant association between grit and the engineering mindset ($\beta = 0.61$, $p < 0.001$). Increased perseverance of effort aligned closely with iterative design and acceptance of failure, signalling that learners who maintain exertion over extended periods are predisposed to iterative, trial-and-error approaches to engineering. A moderate association between consistency of interest and systems thinking was also observed, marking a sustained cognitive and emotional commitment to intricate engineering domains. This dual interrelationship underscores a recursive dynamic: grit supplies the endurance required for mindset-centered actions, while practices rooted in the engineering mindset cultivate the adaptive endurance that, in turn, reinforces and crystallizes grit through successive, mastery-oriented experiences.

6. CONCLUSION

This study provides a comprehensive analysis of grit and the engineering mindset as reciprocal psychological characteristics exerting significant influence on student success in engineering education. Employing advanced psychometric methodologies—namely Structural Equation Modeling and contemporaneous Item Response Theory—we verified the latent multidimensional configuration of each construct and mapped their combined influence on academic resilience, design adaptability, and sustained engagement in complex, iterative problem-solving scenarios. Findings reveal that grit, particularly the dimension of sustained effort, enhances key facets of the engineering mindset: iterative reasoning, a formative view of failure, and a systemic perspective. This integrative lens elucidates the interaction between motivational and cognitive processes in settings that require sustained high achievement. Cohorts registering elevated scores on both grit and engineering mindset outperformed peers on project-centric tasks characterized by uncertainty, thereby providing empirical support for the simultaneous cultivation of psychological and technical competencies. From a design perspective, these results advocate for the development of more cohesive instructional frameworks. Engineering curricula are thus urged to embed grit and mindset development within curricular architecture, evaluative instruments, and student support ecosystems.

Expanding on this perspective, a psychometric lexicon mapping the identified traits can act proprioceptively to detect students at risk, thus permitting the design of tailored interventions that emphasize stamina and cognitive flexibility, while decoupling support from traditional performance indices.

The present research thereby lays the groundwork for forthcoming longitudinal verification, cross-disciplinary comparative studies, and synthesis with AI-augmented adaptive pedagogies. In parallel, it elevates ethical considerations: sustaining universal availability of mindset-sculpting resources, and governing the custody of psychometric data with due prudence. As engineering programmes relentlessly evolve to address complex, boundary-crossing challenges, the intentional fostering of persistent exertion alongside a metacognitive engineering orientation will be requisite for forming practitioners who are robust, inventive, and committed to perpetual self-scrutiny and iterative advancement.
This inquiry thus contributes a foundation for subsequent longitudinal validation, comparative analyses across disciplinary contexts, and integration with AI-facilitated adaptive learning environments. Moreover, it foregrounds ethical imperatives, including the preservation of equitable access to mindset-enhancing interventions and the circumspect management of psychometric information. As engineering curricula continuously adapt to confront intricate, interdisciplinary exigencies, the deliberate cultivation of both sustained effort and a reflective engineering mindset will be essential for nurturing professionals who are resilient, innovative, and capable of ongoing self-assessment and growth.

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