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Changing the Culture in a Senior Design Course to Focus on Grit, Mastery Orientation, Belonging, and Self-Efficacy: Building Strong Academic Mindsets and Psychological Preparedness*

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With the expectation that engineering students ought to be prepared to adapt to a continuously evolving workplace environment to solve the complex problems of the future, engineering educators ought to also adapt and provide innovative learning environments that support not only technical agility, but also psychological agility to support the development of our students. Senior design and capstone courses serve as ideal contexts to support engineering students with this preparation. This paper describes how a senior design course was transformed not in content, but in the classroom values/culture, reward structures, and the learning environment to encourage mastery learning though effort contingencies, grit and perseverance, collaboration, and empowerment. Designed as a pre-test post-test control group design, a set of psychological constructs (grit, sense of belonging, achievement goal orientation, self-efficacy, impulsivity) were administered to a treatment group and a control group to investigate effects of the educational innovations. Effect sizes reveal moderate to high practical significance comparing the treatment and control groups. Psychologically-grounded strategies and important implications for all engineering educators are detailed in this paper.

Keywords: senior and capstone design; goal orientation; grit; effort contingent learning; belonging; self-efficacy

1. Introduction

What if we as faculty could train our students (like coaches train athletes) to not give up, to persevere, to perform at the highest levels, to not lose sight of the end goal, to stay engaged, to belong, and to excel? What if we could shift educational priorities to promote psychological preparation alongside academic preparation?

With the rapid pace of technological change, the future engineer is not only expected to offer technical ingenuity but also to *adapt to a continuously evolving environment* to solve the *complex problems of the future.* The success of the U.S. in global competitiveness is tied directly to the complex problem solving ability of its technical workforce. How can we prepare students to face the complex problems that society requires of engineers to solve? Senior design and capstone courses are an ideal context to help prepare students for the workforce.

Being an engineering student can be tough and usually means facing greater academic challenges. The classes are often harder, the programs are often longer, the grades are often lower, and the commitment and self-discipline required are often greater. To give students the best chance of succeeding in the real world, pedagogical innovations like problem based learning, project based learning, inquiry based learning, and other active learning pedagogies have been implemented for preparing engineering students to face complex problem solving. While often successful, most of these educational strategies have focused on academic and content preparedness, while few have sought to prepare students mentally or psychologically. An inability to cope with the psychological demands of engineering contributes significantly to demotivation and attrition (both in the classroom and potentially in the workplace). Compelling evidence from psychological and educational research suggests that a *proactive approach*, rather than the more common *reactive* approach of targeting "at risk" students (who may feel further alienated for receiving extra attention), could significantly increase students' intrinsic motivation and engagement, leading not only to more grit and persistence, but to better academic performance as well [1].

To be successful, students must be both academically and psychologically prepared for the rigors of not only undergraduate engineering but also real-world engineering practice and embracing the ever changing landscape of complex decision making. Although the vast majority of existing interventions and strategies to improve engineering education are focused on enhancing students' academic preparation by improving structures, content, and curricula, more must be done to support students'

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psychological well-being to maintain the motivation necessary to persist to graduation and to persist in navigating the complex landscape of engineering practice and real-world decision making.

In this study, a variety of psychology-grounded strategies were used in a senior-level design/capstone course to gauge the impacts of psychological preparation and building better academic mindsets in contrast to a control group/course. The study was setup as a pre-test post-test control group design to allow for variations among the control and treatment groups to be explored. Pedagogical and psychological strategies were grounded in relevant psychological theories: achievement goal theory, self-regulation theory, self-determination theory, expectancy value theory, and social identity theory. More specifically, some of the pedagogical strategies used in the treatment course (which shared the same syllabus, course outcomes, content coverage with the control course) included: effort-contingent learning (EFL), mastery-based learning (MBL), problem-based learning (PBL), and a flipped classroom approach. Some of the psychological strategies used in the treatment course included: (1) altering temporal attention and providing performance feedback to facilitate goal-setting, (2) implementing activities to allow for autonomy, (3) establishing a class culture at the onset with shared and student-derived values and behaviors, (4) allowing the exploration of topics enabling personal interest in alignment with course objectives, (5) using interteaching preparation guides, (6) continuously and consistently discussing the relevance of tasks and framing of the tasks to show the value to current and future efforts, (7) continuously and consistently discussing perceived costs of course activities and effort, and (8) using proactive, team-based motivational strategies to support team-activities.

The implications of such findings have broad impacts to other senior design courses, but really to all engineering courses. It is important that we learn from our social science colleagues and the theories that guide how students learn, how students are motivated, how students stay engaged, how students can take ownership of their learning, how students can have autonomy, how students connect with each other and the larger engineering community, how students identify as engineers in social settings, etc. Such work and efforts might be new to engineering educators, but not new to our social science scholars and educators. By understanding psychological theories, engineering educators and all educators will be better positioned to design learning environments that transform our students to be better prepared with dealing with the complexity of engineering practice and life. Educators should start thinking of themselves as coaches rather than individuals who deliver content knowledge.

Acknowledging both academic and psychological demands of complex problem solving, this paper focuses on measuring some of the impacts of reframing a senior level capstone design course sequence (fall and spring) to have a focus on effort, mastery learning, perseverance, engagement, self-efficacy, sense of belonging, forethought in problem solving, etc. The guiding research question being: "how do engineering students' perceptions of learning in a treatment course (designed to support students' academic and psychological preparation) compare to students in a control course (designed as a traditional lecture-based environment focused on primarily content)?"

2. Relevant literature on psychological factors, theories, and frameworks

There are several important psychological constructs that have been found to be impactful to students in learning environments—grit, growth mindset, mastery orientation, intrinsic motivation, sense of belonging, self-efficacy, delayed gratification, etc. A burgeoning educational movement has been exploring the impact of non-cognitive and psychological factors (as opposed to cognitive and academic factors) on student success at all levels. These educators and scholars call for increased research and practice focusing on non-cognitive and psychological components of the student experience [2]. The importance of psychological preparation prior to a challenging task or journey, as well as staying attuned to one's own psychological state during such a task, has been demonstrated in many contexts, perhaps most notably in competitive athletics [3, 4] and the military [5, 6]. Effective psychological preparedness activities often lead to greater resilience and the ability to maintain motivation in the face of uncertainty or self-doubt. In theory, equipping engineering students with such capabilities leads to increased motivation, persistence, performance, and retention.

One of the most prominent of studies showcasing the impacts of non-cognitive and psychological factors has been the Carnegie Foundation's *Pathways to Improvement*, a nationwide initiative of over 28 community colleges exploring a new model of developmental mathematics instruction [7]. The model is unique in that it does not only address the structural and curricular content of math courses, but also engages the socio-emotional and psychological struggles that many college students face. Embedding psychological strategies that lead to "productive persistence," interventions are primarily focused on (1) *shifting mindsets* to help students redefine success, (2) *embedding rigor and relevance* to help students make connections between math and real-world contexts, and (3) *promoting* a *sense of belonging,* the strongest predictor of persistence according to the Carnegie report. Carnegie's educational strategies are producing dramatic results. Before *Pathways to Improvement*, only 6% of developmental mathematics students earned college math credit within their first year of continuous enrollment, and afterwards over 50% were able to do so.

The past decade, the psychological construct of *grit*, a non-cognitive trait encompassing perseverance and passion to pursue goals with sustained effort over time [8]. Grit has been investigated as an explanation for why individuals of similar intelligence succeed in different numbers of objective accomplishments throughout their lives. Grit, which is related to conscientiousness, perseverance, tenacity, and the need for achievement, emphasizes long-term stamina for consistent goals even in the absence of immediate feedback or explicit rewards. Grit was investigated in studies involving grade point average (GPA) of undergraduates, retention in classes at West Point, and ranking in the National Spelling Bee [9]. Grit was a stronger predictor in these contexts than SAT score, GPA, or high school rank. An important take away is that grit changes over time and grit can be taught [10]. Psychological interventions designed to promote grit within engineering student populations are rare. What does it mean to be a gritty engineering student? Prototypically, this is a student who is self-disciplined, who believes in their ability to succeed in engineering (self-efficacy), who can manage their own anxiety, who exhibits prosocial behavior and manages social conflict, who is not afraid of failure, who possesses the self-control required to inhibit impulses and delay gratification when necessary, who is flexible and adapts well to new learning environments, who feels a sense of connectedness and belonging within their program, and whose professional identity strengthens over time. In a sense, grit is the embodiment of numerous other psychological skills and qualities.

Similar to grit, the psychological construct of *growth mindset* has also received attention over the past decade. Proposed by Carol Dweck, there are two general beliefs students may hold about their abilities [11]. Students with a *fixed mindset* believe that intelligence and ability are fixed (so challenges are often avoided because innate limitations are revealed), while students with a *growth mindset* believe that intelligence and ability can be developed (so challenges are embraced because effort is seen as a path to mastery). Prior studies have shown that student confidence can be built by discussing growth mindset in the learning environment and increasing awareness of educational and professional opportunities, choices, and challenges as the focus is shifted from ability to effort [12–14].

Even prior to grit and growth mindset, *students' orientations towards learning* were another set of psychological constructs that received attention from both researchers and educators. A motivational theory, achievement goal theory (AGT) posits that achievement goals may be pursued for reasons that are either intrinsic (*mastery-oriented*) or extrinsic (performance-oriented). Mastery-oriented goals tend to promote long-term, high-quality learning, and college students with a mastery orientation are typically more engaged in class and receive higher grades compared to students with performance goals [15]. Whereas approach goals tend to contribute positively to intrinsic motivation, avoidance goals do not [16].

As might be evident from the psychological constructs described above, there are some common features that become important in well-designed and healthy learning environments (per our knowledge and understanding of important psychological factors and theories). Table 1 shows some of the most relevant psychological theories guiding us in designing environments to promote psychological preparedness and strong academic mindsets. The theories include achievement goal theory, self-determination theory, self-regulation theory, expectancy value theory, and social identity theory. Relevant constructs for each theory are briefly described in Table 1.

Table 1. Relevant psychological theories

Achievement Goal Theory (AGT)
A motivational theory, AGT posits that achievement goals may be pursued for reasons that are either intrinsic (mastery-oriented) or extrinsic (performance-oriented).
Relevant Constructs
Mastery vs. Performance Goal Orientation—Mastery oriented goals tend to promote long-term, high-quality learning, and college students with a mastery orientation are typically more engaged in class and receive higher grades compared to students with performance goals [15].
Approach vs. Avoidance Goal Orientation—Approach goals tend to contribute positively to intrinsic motivation whereas avoidance goals do not [16].

Self-Regulation Theory (SRT)

Individuals can influence their own thoughts and actions. Self-regulation refers to individual processes that are self-directive or self-corrective, such as purposeful behavioral adjustments while pursuing goals [17].

Relevant Constructs

Delay of Gratification—The ability to delay immediate gratification in favor of long-term goals and successfully deploy skills such as impulse control, patience, and willpower has been linked to numerous positive educational outcomes [18].

Emotion Regulation—Referring to a person's ability to understand and influence her emotional experience, a person with good emotion regulation skills can often control impulsive urges [19].

Decision Making—Decisions are usually made under conditions of uncertainty and dealing with this uncertainty is a primary factor in the way students approach decision-making.

Self-Determination Theory (SDT)

SDT is a theory of motivation concerned with supporting individuals' natural tendencies to behave in effective and healthy ways [20–21]. Fulfillment of the three fundamental elements of SDT has been empirically linked to personal and academic success [22–23].

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Competence is the belief that one can influence important outcomes.

Relatedness is the experience of having satisfying and supportive social relationships.

Autonomy is the experience of acting with a sense of choice, volition, and self-determination.

Expectancy Value Theory (EVT)

EVT has three basic components. First, individuals respond to new information by developing a belief about it. Second, they assign a value to each attribute that the belief is based on. Third, expectations are created based on calculations of beliefs and values [24].

Relevant Constructs

Expectancy—Speaks to an individual's expectation that they have the ability or potential needed to execute a course of action or attain a performance outcome [25–26].

Psychological Value—Attainment value refers to the link between a task and a student's own identities and preferences. Greater value leads to greater motivation and effort [26].

Psychological Cost—The costs associated with a goal or task represent perceived obstacles or drawbacks threatening its successful completion. In contemporary versions of EVT, the dimension of psychological cost is inversely related to motivation [27].

Social Identity Theory (SIT)

Groups give individuals a sense of social identity: a sense of belonging to the social world. [28–29] Level of commitment determines how group characteristics, norms, and outcomes will influence the perceptual, affective, and behavioral responses of individuals belonging to that group [30].

Relevant Constructs

In-Group Cooperation and Relatedness—In-group cooperation speaks to collective action and goal pursuit. Willingness to work and bond with others for a common purpose is important to identifying with, and benefitting from, a social group [31–32].

Group Distinctiveness—Perceived positive group distinctiveness facilitates individual pride, commitment, self-esteem by fulfilling inner strivings to feel respected by others [31].

Sense of Belonging—Belonging refers to a need to feel closeness to, and acceptance by, other people, both in dyadic and group contexts [33]. When choosing to leave a group, people often report feelings of improper "fit" or a lack of belonging [33–34].

Further, there are many strategies that can be used to intentionally redesign a learning environment to elicit psychological preparedness and strong academic mindsets. Table 2 showcases some exemplar strategies. This list is by no means all inclusive, but rather serves to highlight some strategies that have been found effective in the literature.

Table 2. Exemplar strategies to build psychological preparedness and strong academic mindsets

Examples of Relevant Strategies to Strengthen Students' Psychological Preparedness

Achievement Goal Theory

(AGT1) Effort Contingent Rewards—Evaluation practices focused on effort rather than ability trigger mastery learning strategies and better knowledge retention [35–37]. In the classroom, extrinsic rewards are often given with good intentions, but they can have detrimental effects when the rewards are perceived as bribes or controlling [38]. When rewards are made contingent on student effort [39], rewards can enhance achievement-directed behavior and even lead to an increase of task persistence [40].

(AGT2) Competency-Based learning (CBL)—CBL is an educational approach that defines learning as the mastering of specific tasks or skills (competencies) required for well-defined *competencies*. The emphasis on assessment provides useful information not only for the students but for the course effectiveness. A benefit to CBL is bridging academic education and industry needs [41–42]. Within engineering education, several studies suggest that CBL results in positive outcomes, such as increased number of internships and first-job hirings [43] as well as better preparation for professional practice [42]. This research is still limited though.

(AGT3) Problem-Based Learning (PBL)—Having historical foundations in medical education [44–45], PBL is a powerful student-centered pedagogy. A large body of literature highlights the successes of PBL in many domains and in support of many different student learning outcomes (e.g., problem solving, critical thinking, motivation, knowledge retention) [46–49]. Although PBL problems can take on a variety of forms [46–48]. PBL problems are typically open-ended with a moderate degree of structuredness, authentic, complex enough to be challenging and engaging to students, adapted to students' cognitive development and prior knowledge, and amenable to problem examination from multiple perspectives [50]. The impacts of a PBL experience or course on constructs of grit, goal orientation, and identity are not well known.

(AGT4) Flipped Classroom—The flipped-classroom approach (or inverted classroom) is an instructional strategy that consists of providing the lecture materials outside the classroom and in an alternative format (e.g. online videos) and utilizing the classroom for applying the knowledge through problem solving, discussion, and active learning strategies. Given that students work at their own pace before attending the class, the teaching format is thought to increase engagement. The role of professors is to mentor and guide students. Although studies in engineering courses present positive outcomes [53–55], there is little empirical research on the impacts of a flipped-classroom.

Self-Regulation Theory

(SRT1) Altering Temporal Attention—Temporal attention alters behavior and showing how the consequences improve alters the "impulsive" behaviors [56]. Orlikowski and Yates [57] determined that temporal structures shape ongoing practices. Related to temporal attention, counseling or instruction in time management strategies leads to improved performance [58–59].

(SRT2) Managing Emotions and Anxiety—Anxiety reduction and emotion management are effective means for reducing academic stress in college students [60]. Disclosing emotions led to significantly better academic performance among college students [61]. Formal instruction and reflection in managing emotions and anxiety (e.g. prior to examinations, project deadlines, etc.) significantly improved student performance [62].

(SRT3) Provide Performance Feedback to Facilitate Goal-setting Activities—Performance feedback improves performance in most cases [63]. Self-set goals and feedback integrated into a system that monitors performance increases performance in goal achievement [64].

(SRT4) Goal Implementation Strategies—With instruction and developmental planning, students map out their own education by creating a personal blueprint for success that is periodically revisited and revised [65]. Formal strategies for detecting conflicts and divergences from goals/requirements is also critical and effective [66].

(SRT5) Helping Students with Decision Making—The way alternatives are presented matter. Placing more weight on long-term goals, rather than immediate gratification [67–69].

Self-Determination Theory

(SDT1) Autonomy and Inductive Teaching Methods—Strategies that allow students to set their own pace with short-term goals or assignment leads to intrinsic motivation [70]. Inductive teaching methods like PBL (mentioned above), inquiry-based learning, case-based teaching, discovery learning, and just-in-time teaching enable students to more effectively solve problems and self-manage goals and their learning [71].

(SDT2) Autonomy-supported Coaching Strategies—Self-monitored and autonomy-supported intentional change produces positive change in behaviors, performance, satisfaction, and persistence [72–73].

(SDT3) Career Exploration—Increased autonomy in diverse opportunities for career exploration results in personally satisfying career decisions for college students [74–75].

(SDT4) Interteaching—The interteaching approach is a non-traditional teaching model that emphasizes independent learning. Students complete a preparation guide before class that includes reading material and questions. At the beginning of class, the professor clarifies difficult concepts emerging from the previous class. Most class time is focused on students working/teaching in pairs. Professors and teaching assistants are available for questions and discussion. At the end of class, students complete a record sheet identifying challenges. Professors use this feedback in preparing for the next lecture. Initial studies report that students prefer, and often learn more, from interteaching compared to traditional lecture classes [76–78]. Interteaching is a relatively new approach, so its adoption in engineering education is limited. Parthasarathy and Jollands [79] found that implementing interteaching in a chemical engineering project-based course improved students' learning and satisfaction. There is still little research on the effectiveness of interteaching in STEM education.

Expectancy Value Theory

(EVT1) Growth Mindset—Student confidence can be built by discussing the growth mindset and increasing awareness of educational and professional opportunities, choices, and challenges as the focus is shifted from ability to effort [12–13, 80]. Increased self-efficacy predicts academic success among students [81]. Self-efficacy is increased based of academic and social feedback [25].

(EVT2) Relevance of Tasks and Reframing the Value—Students are more likely to be engaged in learning if the assigned tasks are perceived to be meaningful and of value to them [82].

(EVT3) Reducing and Reframing Perceived Costs—Creating environments in which perceived academic costs (e.g., effort and time commitments required) are seen as "badges of honor" rather than something to be dreaded or avoided is likely to significantly increase student motivation. This effect is often demonstrated in other contexts such as competitive athletics and the military.

Social-Identity Theory

(SIT1) Proactive, Team-based Motivational Strategies—Highly valued in competitive athletics, the military, and other fields where qualities such as resilience and persistence are essential to success, team-based strategies are effective in building in-group cooperation [83]. Shared task knowledge and shared team knowledge were valid predictors for engineering team performance and success [84].

(SIT2) Team Management and Trust Building—Team cohesion, agreeableness, conscientiousness, collectivism, and preference for teamwork are strong predictors of team performance [85]. "Collective efficacy" reflects trust in the effectiveness of organized community action [86]. Establishing a sense of common experience and purpose in collaborative projects increases the chances of success among team members [87].

(SIT3) Learning Communities—Engineering learning communities and student teams help develop interdisciplinary and social links within a community, as well as lead to increased retention [88].

(SIT4) Mentoring Models—Students with a faculty mentor displayed increased satisfaction and participation in the organization [89]. Similarly, peer support among college students was positively correlated to improved career choices, retention, and fit [90].

(SIT5) Community Service Learning Experiences—Pedagogically related to PBL (described previously), service learning experiences have been shown to expose students to an authentic problem solving and professional environment. Benefits of service learning experiences include social responsibility, professional skill gains, strengthened professional identity, cognitive gains, etc.

3. The context: James Madison University senior-level capstone design courses

The context for this study was a senior design course sequence (treatment group), which comprises of a classroom component as well as a capstone project experience [91]. Prior publications have detailed the vision and content coverage of these courses [92–95]. Previous publications detail the content coverage of the courses that align with the capstone design experience at JMU [95–99].

In alignment with the relevant psychological theories described previously, Table 3 describes the strategies and attributes that detail how the classroom environment was transformed to elicit psychological preparedness and a strong academic mindset.

Table 3. Strategies used in the treatment senior-level design course at James Madison University

Strategies Used in the Treatment Course to Strengthen Students' Psychological Preparedness

Achievement Goal Theory

(AGT1) Effort Contingent Learning and Rewards—In the classroom, extrinsic rewards are often given with good intentions, but they can have detrimental effects when the rewards are perceived as bribes or controlling [38]. When the focus, though, is on effort and the evaluation practices focus on effort rather than ability, such an environment triggers mastery learning strategies and better knowledge retention [40]. Thus, effort contingent learning (ECL), where rewards are made contingent on student effort, can enhance achievement-directed behavior and even lead to an increase of task persistence. The treatment group/course was transformed into a classroom where effort was the emphasis to produce quality work and perform at high standards. The grading rubric that was developed and used aligned with this focus on effort and facilitated the evaluation of student work from the point of view of quality of effort. More specifically, effort was the key emphasis of both in-class activities as well as assignments given to students. Nearly every graded assignment was based on a simple 5-point effort scale that demonstrated to students where the instructor perceived her/his effort to be. Along with an effort rating that was provided with each assignment, in-depth comments were also provided to justify the rating and to describe where there are opportunities for improvement. Students were also encouraged to meet with the instructor for more guidance and clarity on the evaluation of their submitted work. In contrast to the treatment course, most of the graded assignments in the control course were quizzes which were based on a 0–100 grading scale where a student would clearly know which questions she/he got wrong or correct (so the nature of the assignments was more closed-ended with problems that have single correct solutions).

(AGT2) Mastery-Based learning (MBL)—MBL is an educational approach that defines learning as the mastering of specific knowledge and skills. In the treatment course, the course was organized around specific course objectives aligned around four major course modules to elicit mastery learning around the new knowledge to be gained and new skills to be applied. With the focus on mastering the new knowledge and new skills, students were encouraged to put quality effort and evidence mastery learning through their submitted work. Thus, students were allowed to resubmit graded work for a second time in an attempt for them to show deeper understanding and quality effort. Following the grading scheme used in the evaluation of student work per the description in AGT1 above, students in the treatment course were allowed within a specified timeframe (typically within one month) to resubmit their graded work for a chance to demonstrate deeper effort and understanding of the assignment while taking into account the effort rating and qualitative feedback provided by the instructor. This strategy gave control and autonomy to the student to decide if they wanted to invest more effort in order to demonstrate competency and deeper mastery of the content. Although not all students took advantage of this opportunity given to them, most of the students did resubmit revised assignments with demonstrating substantial increased effort. To not disadvantage the instructor will immense amounts of grading, students were informed and expected to submit adequate effort during the first submission of an assignment and only then would they be allowed to resubmit a second time. In other words, if the first submission was poor, the student would not be allowed to submit a second time. Adequate effort was required for the first submission. In contrast, students in the control group were not given a chance for resubmissions for assignments.

(AGT3) Problem-Based Learning (PBL)—PBL problems are typically open-ended with a moderate degree of structuredness, authentic, complex enough to be challenging and engaging to students, adapted to students' cognitive development and prior knowledge, and amenable to problem examination from multiple perspectives [50]. In the treatment course, students were presented four major design challenges that can be described as open-ended because there was not a single, correct answer for each design challenge. Students could follow different paths to get to a solution using the knowledge gained in the course, but also using knowledge they had gained in prior courses in the curriculum. The four major design challenges in the treatment course were designed so that students could demonstrate in an open-ended way the extent to which they understood both the design theory they were being taught, but also the extent to which they could apply such knowledge in a more applied way. These four design challenges focused on embodiment design, psychology of design and human factors engineering, mathematical modeling in making design decisions, as well as parametric design. The paths to getting a solution for these design challenges were many and the approaches that students used also varied. Clarity and justification in the steps and approach that each student took was a must though and this helped in the evaluation. In contrast, students' understanding of content within the four modules in the control group was based primarily from multiple choice quizzes that asked questions which had typically only one correct solution (thus evaluating primarily factual knowledge and understanding)

(AGT4) Flipped Classroom—The flipped-classroom approach (or inverted classroom) was also used in the treatment course. Rather than the traditional model of flipped classrooms in engineering where online videos are made available to students before class, the treatment course utilized *preparation guides* that students were encouraged to complete prior to coming to class. The *preparation guides* were designed and included a series of developmental questions to allow students to demonstrate their understanding of factual knowledge, procedural knowledge, as well as synthesis of new knowledge with previous acquired knowledge (i.e., from prior modules or prior courses). Effort and thinking was needed to complete these guides well, but certainly a requirement of students reading the course book and supplemental content was a must. During class (treatment), the focus was on using active learning to allow students to apply the knowledge they had gained prior to class and to allow application of that knowledge through discussions, case studies, individual and small-group activities, etc. The role of the instructor was thus as a facilitator and mentor to guide students. On some days, particularly with content topics that were more challenging for the students, they were allowed for a portion of class time to compare answers in the *preparation guides* with their peers in small groups. This approach led to collaborative learning and the instructor facilitating important discussions and misconceptions in small group settings but also with the larger class when it became evident that a particular topic would be relevant to the entire class. In contrast, although some active learning took place in the control class, a predominance of traditional PowerPoint lectures was certainly part of the control class.

Self-Regulation Theory

(SRT1) Altering Temporal Attention and Providing Performance Feedback to Facilitate Goal-setting Activities—Per the use of ECL, MBL, and PBL described above, students in the treatment group received timely performance feedback to improve their performance on assignments and to allow them to make a decision on whether or not they would want to invest time to meet a higher level of performance (via the opportunity to resubmit their work to show deeper mastery by the end of the semester). This opportunity to self-set goals and decide if a student wanted to resubmit work served as a vehicle for students to self-regulate their learning, to monitor their performance, and ultimately increase performance in goal achievement. Some flexibility with timing was also given to the students in order to allow them to self-pace, self-assess, and self-monitor their performance in order to help them make a decision about what goals to set and actions to take. This level of self-pacing and self-monitoring gave students the autonomy to decide when and in what order to work on resubmitting their assignments. Each student could decide on which assignment to invest more effort in as well as the timing in which they would turn in the resubmission. Given this autonomy and flexibility that students were given, the instructor also made it clear to students that there would be flexibility on the instructor's end in regard to the grading of the second submission. This was made explicit so that students could understand that grading of the second submission would take more time.

Self-Determination Theory

(SDT1) Autonomy and Inductive Teaching Methods—The strategies described above allowed students in the treatment course to set their own pace with some of the goals of the course. This sense of autonomy leads to intrinsic motivation [98]. Inductive teaching methods like PBL and the flipped classroom model (both mentioned above), enabled students to more effectively solve problems and self-manage goals and their learning.

(SDT2) Establishing the Class Culture via Shared and Student-Derived Values and Behaviors—Autonomy for students was also established during the first day of class, which began with an activity designed to elicit students' beliefs of workplace expectations (peer to peer expectation, supervisor expectations for employees, employee expectations of supervisor, workplace environment, etc.). What derived from this activity became the expectations for the class. The classroom was envisioned as a workplace environment with a derived set of values and expected behaviors. This activity set the culture and tone for the course and from an SDT point-of-view enabled autonomy, relatedness, and competence. Reminders throughout the semester also took place to coach students and to remind them of the goals, culture, and values we had agreed upon for the course. The following questions were the ones asked on that first week of class (treatment) to develop the shared student-driven culture in the class: (1) what knowledge and skills do employers want and expect? (students' responses to this question became what the instructor expected from them—professionalism, adaptability, leadership, initiative, time management, high standards, attention to detail, teamwork, safety, enthusiasm, etc.), (2) what values and behaviors do employers want and expect? (students' responses to this question also became what the instructor expected from them—honesty, integrity, grit, ethics, loyalty, open-mindedness, positive attitude, etc.), (3) what do you expect/want from a workplace environment? (aspects of students' responses guided the design of the classroom environment—positive dynamic environment, opportunities for growth, respect, freedom to diversity, comfortable furniture, flexible work hours, ability to fail and take risk), (4) what do you expect/want from colleagues in the workplace? (students' responses to this question became what the instructor expected from peer students in the class and in team assignments—punctuality, self-awareness, communication, organization, respect, open minded, transparency, positive attitude), (5) what do you expect/want from a supervisor in the workplace? (students' responses to this question laid the foundation for what the instructor strived to achieve as the educator/mentor/facilitator of learning—no micromanagement, guidance, support, mutual respect, clear expectation, leadership, integrity, transparency, honesty), and (6) how should performance in the workplace be evaluated and promotion determined? (students' responses to this question laid the foundation for how the instructor evaluation performance in the classroom—results focused, proactiveness, innovation, effort, quality, collaboration, time management). In contrast, a shared vision and shared culture was not explicitly developed between the instructor and students in the control course.

(SDT3) Exploration of Topics of Interest Related to Course Objectives—Increased autonomy in the treatment course was also established by allowing students to customize some of the design challenges (described previously) to align with their individual interests and career trajectories. This personal touch, yet still aligning with the course objectives, enabled students to personally decide a direction that would yield more intrinsic motivation. One example of such an activity was the psychology of design module, where students were given specific instructions to apply knowledge gained in the course (but also to seek out new knowledge) in order to understand an engineered systems from the lens of psychology and human needs (cognitions, emotions, and behaviors), and to ultimate redesign such an engineered systems having a deeper understanding of human intentions, needs, and behaviors.

(SDT4) Interteaching—As described in the previous tables, the interteaching approach is a non-traditional teaching model that emphasizes independent learning and has received little attention in engineering education contexts. In the treatment course, students completed a *preparation guide* before class that included reading material and questions to not only gain insight to the quality of the reading comprehension, but also to enable application of key concepts of the reading to students' capstone project (which runs concurrently with the lecture as part of the same course). During the class, students were given time to work through the *preparation guides* in pairs or small-groups and the instructor worked to clarify difficult concepts that emerged from the previous preparation guides as well as the one being worked on during class. At the end of class, students completed a record sheet identifying challenges and the instructor used this feedback in preparing for the next lecture. In contrast, the control class used assigned readings as the preparation for the in-class sessions.

Expectancy Value Theory

(EVT1) Relevance of Tasks and Reframing the Value—Throughout the semester, the relevance of tasks and assignments was explicitly framed and presented to students. Connections were made explicit around topics within the course, but also with other courses in the curriculum, as well as the relevance of work to future employment opportunities. Such connections enabled students to remain engaged in the learning and to also see value and meaning to the work we were doing in the course not only for earning their degree but also in seeing the value beyond their undergraduate tenure. This strategy was something that required conversation and discussion in class to keep students focused on the shared vision that students and instructor set for the course and then following through with execution of effort and quality work.

(EVT2) Reducing and Reframing Perceived Costs—The treatment course was also framed as an environment in which perceived academic costs (e.g. effort and time commitments required) were seen as "badges of honor" rather than something to be dreaded or avoided. Discussions and activities enabled a reframing of the perceived costs of time and effort. Explicit links to the importance of such knowledge and skills to future employment were made in order to sustain student motivation. Autonomy (described above) also helped with this reframing and allowed students to self-pace their learning, but also own their learning in the course. When students were in midst of challenging and busy times of the semester (i.e., multiple tests in one week, a big report or deliverable being due for capstone, etc.), the instructor was constantly reminding them of self-pacing, self-monitoring, and the autonomy they were given to resubmit their work, to focus on effort, and pacing their commitments.

Social-Identity Theory

(SIT1) Using Proactive, Team based Motivational Strategies to Support Team Activities/Projects—Highly valued in competitive athletics, the military, and other fields where qualities such as resilience and persistence are essential to success, team-based strategies are effective in building in-group cooperation. Team cohesion, authentic collaboration, and collective efficacy were frequently discussed in the course to motivate not only completion of team-based course assignments, but also capstone projects. Discussions and activities targeting team performance and "collective efficacy" helped to establish a sense of common experience and purpose in collaborative capstone projects. Professional articles around effective strategies and knowledge of top performing teams were also shared and discussed with students. Such discussions enabled for establishing a sense of purpose in collaborative projects as a means to enhance the common experience and chances of individual and team success.

4. Methodology

This study was designed as a pre-test post-test control group design, which is common in educational research settings to investigate effects in educational innovations. The pre-test and post-test were exactly the same and were respectively administered a few of days prior to the start of the semester and during the last week of the semester. The surveys included the following measures:

1. **Short Grit Scale (Grit-S):** A short version of the Grit Scale, Grit-S [99, 100], was used to measure *consistency of interest* and *perseverance of effort.* Grit-S is supported with adequate internal consistency [104]. Only *perseverance of effort* was administered in this study.
2. **Achievement Goal Questionnaire (AGQ):** Grounded in achievement goal theory (see above), the subscales of AGQ are *mastery-approach* (students work hard to master the material), *performance-approach* (students work hard for to do well in the eyes of others), *mastery-avoidance* (students work hard to avoid not mastering the material), and *performance-avoidance* (students work hard in order to avoid looking foolish in front of others). AGQ items are supported with adequate internal consistency [101].
3. **Dickman Dysfunctional Impulsivity Scale:** Defined as "the tendency to act with less forethought than most people of equal ability when this tendency is a source of difficulty, [102, 103]" dysfunctional impulsivity was assessed in the context of engineering problem solving.
4. **Sense of Belonging:** This subscale was adapted from the perceived cohesion scale [104] and theory to measure sense of "fit" and "belonging."
5. **Self-Efficacy**: Derived from self-efficacy literature [105], the subscale included was *self-efficacy for academic achievement*.

Participants in this study included senior engineering students in two sections of the same course that shared the same syllabus and content coverage. One section served as the control group and the other as the treatment group. There were 30 students in the control group/section and 31 in the treatment group/section. Section placement was based on keeping capstone teams in the same section. The demographics were similar in both groups with about 20% female students. Both sections, control and treatment groups, completed the same pre and post survey. In the control group, 27 students completed the pre-survey (corresponding to a 90% response rate) and 20 students completed the post-survey (corresponding to a 67% response rate). In the treatment group, 28 students completed the pre-survey (corresponding to a 90% response rate) and 23 students completed the post-survey (corresponding to a 74% response rate).

Data analysis involved both descriptive statistics and analysis of effect sizes, which are quantitative measures of the strength of a phenomenon and a simple way of quantifying the difference between two groups, which has many advantages over the use of tests of statistical significance alone. Effect size places an emphasis on the size of the difference rather than confounding this with sample size. In pre-test post-test control group designs, it has been suggested that effect size should be based on the mean pre-post change in the treatment group minus the mean pre-post change in the control group, divided by the pooled pretest standard deviation [106].

$$Effect\ Size = \frac{(M_{post,T} - M_{pre,T}) - (M_{post,C} - M_{pre,C})}{SD_{pre,pooled}} \quad (1)$$

5. Results and discussion

Figure 1 and Table 4 highlight the data and findings from this pre-test post-test control group design study. Fig. 1 shows pre-survey and post-survey mean scores for the control and treatment groups across the seven psychological constructs administered: (a) grit (perseverance of effort), (b) dysfunctional impulsivity, (c) self-efficacy, (d) sense of belonging, (e) mastery approach orientation, (f) performance approach orientation, (g) work avoidance orientation. Overall, pre-survey mean scores across the control and treatment groups show consistency among the students. Students entering this course, who are seniors, perceive themselves to be somewhat gritty, somewhat impulsive (i.e., tendency to act with less forethought than their peers with equal ability when the tendency is a source of difficulty), with good self-efficacy of their academic achievement, with a fairly strong sense of belonging, with a somewhat high mastery orientation towards learning, with a somewhat lower (compared to mastery orientation) performance orientation towards learning which is healthy (e.g. research shows that higher mastery orientation is more adaptive than a higher performance orientation), and somewhat low on work avoidance. These characteristics paint a picture of seniors at this institution at the beginning of their senior academic year and tend to make sense for what we would expect for these students who have survived three to five years in their tenure as an undergraduate. In contrast to post-survey results, we do see larger discrepancies among the control and treatment groups, but the significance of these differences is to be discussed in the following paragraphs via effect size analysis. Overall, post-survey mean scores across the control and treatment groups show the following: (a) treatment group students rating themselves more gritty (perseverance of effort) compared to the control group students, but overall less gritty than their pre-survey ratings, (b) treatment group students rating themselves less impulsive than both the control group students and their pre-survey ratings, (c) treatment group students rating themselves with higher sense of self-efficacy compared to the control group students, but slightly lower than their pre-survey mean ratings, (d) treatment group students revealing a higher sense of belonging compared to the control group students, but slightly lower than their pre-survey mean ratings, (e) treatment group students revealing a higher mastery orientation towards learning compared to the control group students, but slightly lower than their pre-survey mean ratings, (f) treatment group students revealing a slightly higher performance orientation towards learning compared to the control group students, and (g) treatment group students revealing a lower work avoidance orientation towards learning compared to the control group students, and also less work avoidant compared to their pre-survey mean ratings. Several of the pre-survey mean ratings are higher than the post-survey mean ratings and this could be due to students overestimating their abilities/perceptions prior to the course. Comparing post-survey results only, though, it is consistent that mean scores for the treatment group are at higher/better levels in contrast to the control group.

Table 4 summarizes the findings in comparing pre-test post-test responses of the treatment and control groups. Although not shown, comparing effect sizes (Cohen's d) across treatment and control groups on pre-survey responses, the results revealed that there are either small or very small effects evident across the measures. This suggests that the two groups were very similar in their responses during the pre-survey and there was no practical significance among them. Upon analyzing both post-test and pre-test responses for the treatment and control groups though (based on Equation 1), practical significant findings are evident. Nearly across all the measures, the difference between control and treatment groups suggested moderate to high practical significance. The only metric that did not reveal a moderate or high practical significance was sense of belonging. For all other measures, the treatment group revealed higher ratings than the control group and at least moderate practical significance. These differences are detailed in Table 3. Such findings suggest that the innovations implemented and the culture established in the treatment classroom revealed practical significance in contrast to the control group.

Although not a necessary component of this study, there are several responses in the end-of-semester course evaluation from students in the treatment course that further showcased the positive outcomes of how the class was setup and showcased the positive outcomes of the strategies used in the class. Some of these quotes are evident here:

"*Completing the interteaching guides and reading the textbook was an important part of learning the material.*"

"*Interteaching guides and redoing assignment was very beneficial. It allowed me to keep reviewing the material.*"

"*The workplace-like culture and expectations of this*

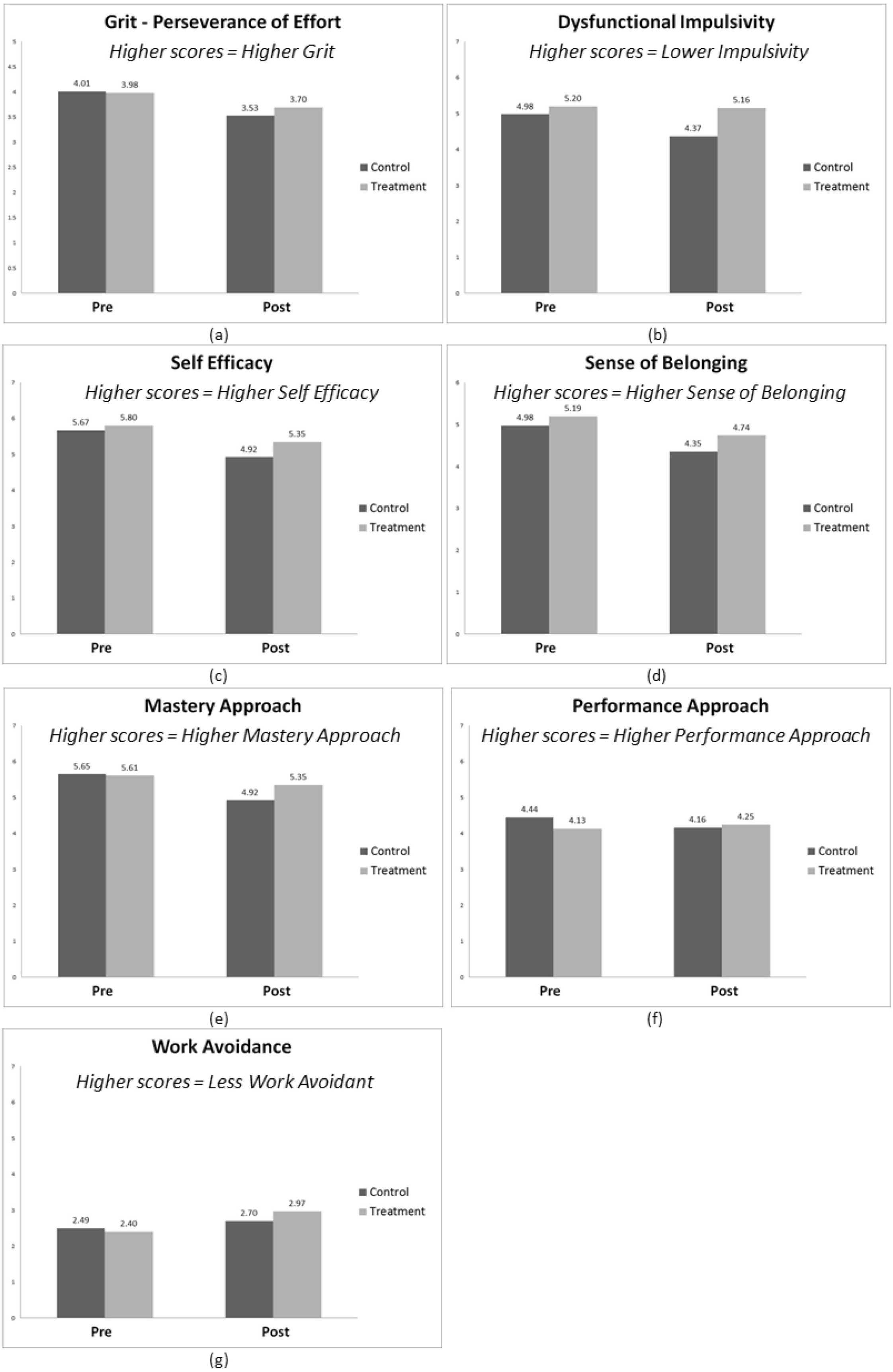

Fig. 1. Pre-survey and post-survey mean scores for the control and treatment groups across the seven psychological constructs administered: (a) grit (perseverance of effort), (b) dysfunctional impulsivity, (c) self-efficacy, (d) sense of belonging, (e) mastery approach orientation, (f) performance approach orientation, (g) work avoidance orientation.

Table 4. Treatment vs control group effect size results

Construct	Effect Size	Summary of Results
Grit (4 items) (5pt scale)	0.30 **Moderate Effect**	The treatment group revealed grittier students than the control group and thus revealing a higher desire for sustained effort and perseverance of effort on engineering tasks related to the course but also engineering tasks in general.
Impulsivity (3 items) (7pt scale)	0.62 **Moderate to High Effect**	The treatment group less impulsive than the control group, revealing higher forethought during problem solving. The implications here are the students in the treatment group reveal a higher tendency for planning and forethought in problem solving even when dealing with difficult problems.
Sense of Belonging (3 items) (6pt scale)	0.20 **Small Effect**	The treatment group showed stronger sense of belonging than the control group, thus revealing a stronger sense of belonging with the larger class and belonging to the engineering, which has been shown to have implications towards persistence.
Self-Efficacy (2 items) (7pt scale)	0.30 **Moderate Effect**	The treatment group revealed higher degree of self-efficacy than the control group, thus highlighting a higher degree of a student having confidence in her/his abilities.
Mastery Approach (2 items) (7pt scale)	0.51 **Moderate to High Effect**	The treatment group revealed a higher degree of mastery orientation than the control group and thus revealing a deeper desire to learn and master the course content better. Higher mastery orientation is a healthier and more adaptive orientation towards learning.
Performance Approach (3 items) (7pt scale)	0.30 **Moderate Effect**	The treatment group revealed a slightly higher degree of performance orientation than the control group, thus revealing a desire to perform better than one's peers. Although a higher performance orientation is not always adaptive, the combination of higher mastery approach with a higher performance approach is adaptive.
Work Avoidance (3 items) (7pt scale)	0.30 **Moderate Effect**	The treatment group less work avoidant than the control group, thus revealing a reduced desire to doing the minimum amount of work possible. Being less work avoidant is a healthier and more adaptive mode of learning as evidenced in the treatment group.

course were always looked forward to. It actually made class enjoyable to go to. It treated us more like adults rather than students."

"*I really enjoyed the workplace-like culture and expectations of this course because it has helped us prepare for the real world once we graduate*."

"*It was a very refreshing way to approach class. It was the best class environment I have participated in.*"

"*Could not have gotten through this entire program without grit. I'll think of grit a lot as I begin the next chapters of my life.*"

6. Conclusions

In this study, a variety of psychology-grounded strategies were used in a senior-level design/capstone course to gauge the impacts of psychological preparation and building better academic mindsets in contrast to a control group/course. The study was setup as a pre-test post-test control group design to allow for variations among the control and treatment groups to be explored. Overall practical significant findings revealed strong and positive outcomes for the treatment group which showcased students with (a) more grit and perseverance of effort, (b) more forethought in problem solving even when dealing with difficult problems, (c) a higher sense of belonging with peers and engineering, (d) a higher sense of self-efficacy and confidence in their abilities, (e) a higher mastery and performance orientation towards learning, and (f) less work avoidant when dealing with time-consuming engineering tasks. Such outcomes were achieved by incorporating pedagogical and psychological strategies grounded in relevant psychological theories: achievement goal theory, self-regulation theory, self-determination theory, expectancy-value theory, and social identity theory. More specifically, some of the pedagogical strategies used in the treatment course (which shared the same syllabus, course outcomes, content coverage with the control course) included: effort contingent learning (EFL) and rewards, mastery-based learning (MBL), problem-based learning (PBL), and a flipped classroom approach. Some of the psychological strategies used in the treatment course included: (1) altering temporal attention and providing performance feedback to facilitate goal-setting, (2) implementing activities to allow for autonomy, (3) establishing a class culture at the onset with shared and student-derived values and behaviors, (4) allowing the exploration of topics enabling personal interest in alignment with course objectives, (5) using interteaching preparation guides, (6) continuously and consistently discussing the relevance of tasks and framing of the tasks to show the value to current and future efforts, (7) continuously and consistently discussing perceived costs of course activities and effort, and (8) using proactive, team-based motivational strategies to support team-activities.

7. Implications and limitations

What if we as faculty could train our students (like coaches train athletes) to not give up, to persevere, to perform at the highest levels, to not lose sight of the end goal, to stay engaged, to belong, and to excel? What if we could shift educational priorities to promote psychological preparation alongside academic preparation?

Being an engineering student can be tough and usually means facing greater academic challenges. The classes are often harder, the programs are often longer, the grades are often lower, and the commitment and self-discipline required are often greater. To give students the best chance of succeeding in the real world, we must prepare them not only in learning technical content better through pedagogical innovations, but also support them to cope with the psychological demands of engineering that contribute significantly to demotivation and attrition (both in the classroom and potentially in the workplace). To be successful, students must be both academically and psychologically prepared for the rigors of not only undergraduate engineering but also real-world engineering practice and embracing the ever changing landscape of complex decision making.

The implications of this study have broad impacts to other senior design courses, but really to all engineering courses. Design and capstone courses being culminating courses that support theory and practice connections in typical curricula may be best positioned for integrating novel models such as the one described in this paper in support of students' psychological preparation and positive academic mindset. The implications though are to all engineering educators. It is important that we learn from our social science colleagues and the theories that guide how students learn, how students are motivated, how students stay engaged, how students can take ownership of their learning, how students can have autonomy, how students connect with each other and the larger engineering community, how students identify as engineers in social settings, etc. Such work and efforts might be new to engineering educators, but not new to our social science scholars and educators. By understanding psychological theories, engineering educators and all educators will be better positioned to design learning environments that transform our students to be better prepared with dealing with the complexity of engineering practice and life. Educators should start thinking of themselves as coaches rather than individuals who deliver content knowledge. We must embrace a more holistic view of our role as educators and understand that our job goes beyond delivery of content knowledge. We need to facilitate learning in a way that supports not only our students' content knowledge understanding, but also supports their development as individuals. Like coaches of an athletic team, we need to teach both the technical skills but also the psychological preparation of our students. This paper is a small example of what could be achieved when educators reframe their role in the classroom and focus not only on content delivery, but psychological and academic preparation to instill adaptive and healthy mindsets for our students.

There are several limitations with this study. Although the control and treatment courses shared the same syllabus, same course objectives, same content coverage, there were also differences that may cofound the findings. One limitation is the fact that two different instructors taught this course. Whereas one instructor (control group) focused on content delivery outlined in the syllabus, the other instructor (treatment group) focused on much more than the content coverage and demonstrated use of active learning pedagogies and psychological strategies. Because the instructor was not the same for this study, some of the findings may be cofounded. Although the pre-test post-test control group design is appropriate and a more rigorous approach to just post-test comparisons, the study does represent a small sample size and one semester of data. Further, another limitation is the response rate from pre-test to post-test, which did drop because the end of the semester is commonly known to be a busier time of the year for students.

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References

1. D. S. Yeager and G. M. Walton, Social-psychological interventions in education: They're not magic, *Review of Educational Research*, **81**(2), 2011, pp. 267–301.
2. C. A. Farrington, M. Roderick, E. Allensworth, J. Nagaoka, T. S. Keyes, D. W. Johnson and N. O. Beechum,

Teaching Adolescents to Become Learners: The Role of Noncognitive Factors in Shaping School Performance—A Critical Literature Review, *Consortium on Chicago School Research*, 1313 East 60th Street, Chicago, IL 60637, 2012.
3. D. Gill and L. Williams, *The Psychological Dynamics of Sport and Exercise* (3rd Edition), Chicago: Human Kinatics Publishing, 2008.
4. R. Cox, *Sports Psychology: Concepts and Applications*, New York: McGraw Hill, 2011.
5. L. S. Meredith, C. D. Sherbourne, S. Gaillot, L. Hansell, H. V. Ritschard, A. M. Parker and G. Wrenn, *Promoting Psychological Resilience in the U.S. Military,* Santa Monica, CA: Rand Publishing, 2011.
6. R. T. Keller, N. Greenberg, W. V. Bobo, P. Roberts, N. Jones and D. Orman, Soldier peer mentoring care and support: Bringing psychological awareness to the front, *Military Medicine*, **170**, 2005, pp. 355–361.
7. E. Silva and T. White, *Pathways to Improvement: Using Psychological Strategies to Help College Students Master Developmental Math*. Carnegie Foundation, 2013.
8. A. L. Duckworth, C. Peterson, M. D. Matthews and D. R. Kelly, Grit: perseverance and passion for long-term goals, *Journal of Personality and Social Psychology*, **92**(6), 2007, 1087.
9. A. L. Duckworth, P. D. Quinn and M. E. Seligman, Positive predictors of teacher effectiveness. *The Journal of Positive Psychology*, **4**(6), 2009, pp. 540–547.
10. L. Eskreis-Winkler, A. L. Duckworth, E. P. Shulman and S. Beal, The grit effect: predicting retention in the military, the workplace, school and marriage, *Frontiers in Psychology*, **5**, 2014, p. 36.
11. Dweck C., *Mindset: The new psychology of success*. Random House Digital, Inc., 2006.
12. C. S. Dweck and E. L. Leggett, A social-cognitive approach to motivation and personality, *Psychological Review*, **95**(2), 1988, p. 256.
13. E. S. Elliot and C. S. Dweck, Goals: an approach to motivation and achievement, *Journal of Personality and Social Psychology*, **54**(1), 1988, pp. 5.
14. S. J. Lopez and M. C. Louis, The principles of strengths-based education, *Journal of College and Character*, **10**(4), 2009.
15. J. M. Harackiewicz, K. E. Barron, S. M. Carter, A. T. Lehto and A. J. Elliot, Predictors and consequences of achievement goals in the college classroom: Maintaining interest and making the grade, *Journal of Personality and Social psychology*, **73**(6), 1997, p. 1284.
16. A. J. Elliot and M. A. Church, A hierarchical model of approach and avoidance achievement motivation, *Journal of Personality and Social Psychology*, **72**(1), 1997, p. 218.
17. K. D. Vohs and R. F. Baumeister (Eds.), *Handbook of self-regulation: Research, theory, and applications*. Guilford Press, 2011.
18. H. Bembenutty, Sustaining motivation and academic goals: The role of academic delay of gratification, *Learning and Individual Differences*, **11**(3), 1999, pp. 233–257.
19. J. J. Gross (Ed.), *Handbook of emotion regulation*, New York, NY: Guilford Press, 2007.
20. E. L. Deci and R. M. Ryan, The empirical exploration of intrinsic motivational processes, *Advances in Experimental Social Psychology*, **13**(2), 1980, pp. 39–80.
21. R. M. Ryan and E. L. Deci, Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being, *American Psychologist*, **55**(1), 2000, p. 68.
22. E. L. Deci, R. J. Vallerand, L. G. Pelletier and R. M. Ryan, Motivation and education: The self-determination perspective, *Educational Psychologist*, **26**(3–4), 1991, pp. 325–346.
23. M. Vansteenkiste, R. M. Ryan and E. L. Deci, Self-determination theory and the explanatory role of psychological needs in human well-being. In L. Bruni, F. Comim and M. Pugno (Eds.), *Capabilities and Happiness*, pp. 187–223, Oxford: Oxford University Press, 2008.
24. A. Wigfield and J. S. Eccles, Expectancy—value theory of achievement motivation. *Contemporary Educational Psychology*, **25**(1), 2000, pp. 68–81.
25. A. Bandura, Self-efficacy: Towards a unifying theory of behavioral change, *Psychology Review*, **84**, 1977, pp. 192–215.
26. J. A. Eccles, Motivational perspective on school achievement: Taking responsibility for learning and teaching. In. R. J. Sternberg and R. F. Subotnik (Eds.), *Optimizing student success in schools with the new three Rs,* 2007, pp. 199–202, Charlotte, NC: Information Age.
27. C. S. Hulleman, S. M. Schrager, S. M. Bodmann and J. M. Harackiewicz, A meta-analytic review of achievement goal measures: Different labels for the same constructs or different constructs with similar labels, *Psychological bulletin*, **136**(3), 2010, p. 422.
28. H. E. Tajfel, *Differentiation between social groups: Studies in the social psychology of intergroup relations*, Academic Press, 1978.
29. H. Tajfel and J. C. Turner, An integrative theory of intergroup conflict. *The Social Psychology of Intergroup Relations*, **33**, 1979, p. 47.
30. N. Ellemers, R. Spears and B. Doosje, Self and Social Identity. *Annual Review of Psychology*, **53**(1), 2002, pp. 161–186.
31. H. Tajfel, Social psychology of intergroup relations. *Annual Review of Psychology*, **33**(1), 1982, pp. 1–39.
32. J. M. LaRocco, J. S. House and J. R. French Jr, Social support, occupational stress, and health. *Journal of Health and Social Behavior*, 1980, pp. 202–218.
33. V. L. Vignoles, C. Regalia, C. Manzi, J. Golledge and E. Scabini, Beyond self-esteem: Influence of multiple motives on identity construction, *Journal of Personality and Social Psychology*, **90**(2), 2006, p. 308.
34. J. S. Eccles and C. Midgley, Stage-environment fit: Developmentally appropriate classrooms for young adolescents, *Research on Motivation in Education*, **3**, 1989, pp. 139–186.
35. C. Ames, Achievement attributions and self-instructions under competitive and individualistic goal structures, *Journal of Educational Psychology*, **76**(3), 1984, p. 478.
36. C. Ames, Competitive, cooperative, and individualistic goal structures: A cognitive-motivational analysis, *Research on Motivation in Education*, **1**, 1984, pp. 177–207.
37. S. Graham and S. Golan, Motivational influences on cognition: Task involvement, ego involvement, and depth of information processing, *Journal of Educational Psychology*, **83**(2), 1991, p. 187.
38. M. R. Lepper and M. Hodell, Intrinsic motivation in the classroom, *Research on Motivation in Education*, **3**, 1989, pp. 73–105.
39. J. Brophy, Synthesis of Research on Strategies for Motivating Students to Learn, *Educational Leadership*, **45**(2), 1987, pp. 40–48.
40. A. Miller and H. L. Hom, Influence of extrinsic and ego incentive value on persistence after failure and continuing motivation, *Journal of Educational Psychology*, **82**(3), 1990, p. 539.
41. J. A. Bowden, Competency-based learning, *Connotative Learning: The Trainer's Guide to Learning Theories and Their Practical Application to Training Design*, 2004, **91**.
42. A. Bright and J. R. Phillips, The Harvey Mudd engineering clinic past, present, future, *Journal of Engineering Education*, **88**(2), 1999, pp. 189–194.
43. H. Witt, J. R. Alabart, F. Giralt, J. Herrero, L. Vernis and M. Medir, A competency-based educational model in a chemical engineering school, *International Journal of Engineering Education*, **22**(2), 2006, p. 218.
44. H. S. Barrows, A taxonomy of problem-based learning methods, *Medical Education*, **20**(6), 1986, pp. 481–486.
45. H. S. Barrows and R. M. Tamblyn, *Problem-based learning: An approach to medical education* (Vol. 1). Springer Publishing Company, 1980.
46. E. De Graaf and A. Kolmos, History of problem-and project-based learning. *Management of change, Implementation of Problem Based and Project Based Learning in Engineering,* Rotterdam, Sense Publishers, 2007.
47. X. Du, E. D. Graaff and A. Kolmos, 2009, PBL–Diversity in Research Questions and Methodologies, *Research on PBL practice in engineering education*, 2009, pp. 1–9.

48. D. R. Woods, *Problem-based learning: How to gain the most from PBL*, Waterdown, Canada: DR Woods, 1994.
49. H. G. Schmidt, Problem-based learning: Rationale and description, *Medical Education*, **17**(1), 1983, pp. 11–16.
50. D. H. Jonassen and W. Hung, All problems are not equal: Implications for problem-based learning, *Interdisciplinary Journal of Problem-Based Learning*, **2**(2), 2008, p. 4.
51. J. Ravitz, Introduction: Summarizing findings and looking ahead to a new generation of PBL research, *Interdisciplinary Journal of Problem-based Learning*, **3**(1), 2009, p. 2.
52. J. R. Savery, Overview of problem-based learning: Definitions and distinctions, *Interdisciplinary Journal of Problem-based Learning*, **1**(1), 2006, pp. 3.
53. J. L. Falconer, J. deGrazia, W. Medlin and M. P. Holmberg, Using screencasts in ChE courses. *Chemical Engineering Education*, **43**(4), 2009, pp. 302–305.
54. J. Foertsch, G. Moses, J. Strikwerda and M. Litzkow, "Reversing the Lecture/Homework Paradigm Using eTEACH® Web-based Streaming Video Software," *Journal of Engineering Education*, **91**(3), 2002, pp. 267–274.
55. R. Toto and H. Nguyen, "Flipping the work design in an industrial engineering course," *Frontiers in Education Conference*, 2009, 39th IEEE, pp. 1–4.
56. P. T. Radu, R. Yi, W. K. Bickel, J. J. Gross and S. M. McClure, A mechanism for reducing delay discounting by altering temporal attention, *Journal of the Experimental Analysis of Behavior*, **96**(3), 2011, pp. 363–385.
57. W. J. Orlikowski and J. Yates, It's about time: Temporal structuring in organizations, *Organization Science*, **13**(6), 2002, pp. 684–700.
58. R. Misra and M. McKean, College Students' Academic Stress and Its Relation to their Anxiety, Time Management, and Leisure Satisfaction, *American Journal of Health Studies*, **16**(1), 2000, pp. 41–51.
59. M. T. Trockel, M. D. Barnes D. L. and Egget, Health-related variables and academic performance among first-year college students: Implications for sleep and other behaviors, *Journal of American College Health*, **49**(3), 2000, pp. 125–131.
60. H. Gerdes and B. Mallinckrodt, Emotional, social, and academic adjustment of college students: A longitudinal study of retention, *Journal of Counseling and Development*, **72**(3), 1994, pp. 281–288.
61. M. A. Lumley and K. M. Provenzano, Stress management through written emotional disclosure improves academic performance among college students with physical symptoms, *Journal of Educational Psychology*, **95**(3), 2003, p. 641.
62. C. W. Struthers, R. P. Perry and V. H. Menec, An examination of the relationship among academic stress, coping, motivation, and performance in college, *Research in Higher Education*, **41**(5), 2000, pp. 581–592.
63. A. N. Kluger and A. DeNisi, The effects of feedback interventions on performance: a historical review, a meta-analysis, and a preliminary feedback intervention theory, *Psychological Bulletin*, **119**(2), 1996, p. 254.
64. M. A. Campion and R. G. Lord, A control systems conceptualization of the goal-setting and changing process, *Organizational Behavior and Human Performance*, **30**(2), 1982, pp. 265–287.
65. E. M. Smith, B. J. Beggs, A. Robinson and W. Middleton, Personal Development Planning for Student Retention and Progression in Engineering, *Progress 3 Conference, University of Hull*, 2003.
66. A. Van Lamsweerde, R. Darimont and E. Letier, Managing conflicts in goal-driven requirements engineering, *Software Engineering, IEEE Transactions*, **24**(11), 1998, pp. 908–926.
67. E. Magen, C. S. Dweck and J. J. Gross, The Hidden-Zero Effect Representing a Single Choice as an Extended Sequence Reduces Impulsive Choice, *Psychological Science*, **19**(7), 2008, pp. 648–649.
68. W. Mischel, Y. Shoda and M. L. Rodriguez, Delay of gratification, *Choice over Time*, **147**, 1992.
69. R. F. Baumeister, Yielding to temptation: Self-control failure, impulsive purchasing, and consumer behavior, *Journal of Consumer Research*, **28**(4), 2002, pp. 670–676.
70. W. S. Grolnick and R. M. Ryan, Autonomy in children's learning: An experimental and individual difference investigation, *Journal of Personality and Social Psychology*, **52**(5), 1987, p. 890.
71. M. J. Prince and R. M. Felder, Inductive teaching and learning methods: Definitions, comparisons, and research bases, *Journal of Engineering Education*, **95**(2), 2006, pp. 123–138.
72. J. O. Prochaska, W. F. Velicer, J. S. Rossi, M. G. Goldstein, B. H. Marcus, W. Rakowski, C. Fiore, L. L. Harlow, C. A. Redding, D. Rosenbloom and S. R. Rossi, Stages of change and decisional balance for 12 problem behaviors, *Health Psychology*, **13**(1), 1994, p. 39.
73. M. Benton, J. Pappas and E. Pappas, "WordPress+Qualtrics: A Plugin Supporting Research and New Pedagogy to Develop Personal Sustainability via 360° Evaluation," *AMCIS 2011: 17th Americas Conference on Information Systems*, Detroit, August 2011.
74. A. L. Guerra and J. M. Braungart-Rieker, Predicting career indecision in college students: The roles of identity formation and parental relationship factors, *The Career Development Quarterly*, **47**(3), 1998, pp. 255–266.
75. D. A. Luzzo, T. James and M. Luna, Effects of attributional retraining on the career beliefs and career exploration behavior of college students, *Journal of Counseling Psychology*, **43**(4), 1996, p. 415.
76. K. Saville Bryan, T. E. Zinn, N. A. Neef, R. Van Norman and S. J. Ferreri, "A comparison of interteaching and lecture in the college classroom," *Journal of Applied Behavior Analysis*, **39**(1), 2006, pp. 49–61.
77. E. Arntzen and K. Hoium, On the effectiveness of interteaching, *The Behavior Analyst* Today, **11**, 2010, pp. 155–159.
78. A. Scoboria and A. Pascual-Leone, An 'Interteaching' informed approach to instructing large undergraduate classes, *Journal of the Scholarship of Teaching and Learning*, **9**, 2009, pp. 29–37.
79. R. Parthasarathy and M. Jollands, Interteaching in a second year chemical engineering undergraduate project-based course, *Profession of Engineering Education: Advancing Teaching, Research and Careers, The: 23rd Annual Conference of the Australasian Association for Engineering Education,* 2012, p. 455. Engineers Australia.
80. S. J. Lopez and M. C. Louis, The principles of strengths-based education, *Journal of College and Character*, **10**(4), 2009.
81. M. Bong, Role of self-efficacy and task-value in predicting college students' course performance and future enrollment intentions, *Contemporary Educational Psychology*, **26**(4), 2001, pp. 553–570.
82. C. Ames, Classrooms: Goals, structures, and student motivation, *Journal of Educational Psychology*, **84**(3), 1992, p. 261.
83. Clark D. A., *The Capability Approach: Its Development, Critiques and Recent Advances*, 2005.
84. F. Mistree, D. Ifenthaler and Z. Siddique, Empowering engineering students to learn how to learn: A competency-based approach, *American Society for Engineering Education National Conference,* June 2013, Atlanta, Georgia.
85. S. Bell, Deep-level composition variables as predictors of team Performance: A meta-Analysis, *Journal of Applied Psychology*, **92**(3), 2007, pp. 595–615.
86. D. Perkins and D. Long, Neighborhood sense of community and social capital: A multi-level analysis, In A. Fisher, C. Sonn and B. Bishop (Eds.), *Psychological sense of community: Research, applications, and implications*, pp. 291–318, New York: Plenum, 2002.
87. McMillan D. W., Sense of community, *Journal of Community Psychology*, **24**(4), 1996, pp. 315–325.
88. J. E. Froyd and M. W. Ohland, Integrated engineering curricula, *Journal of Engineering Education*, **94**(1), 2005, pp. 147–164.
89. F. Mael and B. E. Ashforth, Alumni and their alma mater: A partial test of the reformulated model of organizational identification, *Journal of Organizational Behavior*, **13**(2), 1992, pp. 103–123.

90. D. E. Felsman and D. L. Blustein, The role of peer relatedness in late adolescent career development, *Journal of Vocational Behavior*, **54**(2), 1999, pp. 279–295.
91. O. Pierrakos, E. Barrella, K. Stoup, On the Impacts of Panel-based Technical Design Reviews: From Implementation to Mixed-Methods Evidence, *International Journal of Engineering Education*, **31**(6(B)), 2015, pp. 1844–1859.
92. O. Pierrakos, R. Nagel, H. Watson, K. Gipson, E. Barrella, E. Pappas, R. Anderson, J. Karabelas, I. El-Adaway, S. Yazdani and R. Kander, All Problems Are Not Created Equal: Intentional Design of Learning Experiences Grounded on an Innovative and Versatile Problem Based Learning Model, *5th Annual Conference on Higher Education Pedagogy*, February 2013, Blacksburg, Virginia.
93. O. Pierrakos and E. Barrella, On the Use of Design Reviews during a Two-Year Capstone Design Experience: The James Madison University Model, *Capstone Design Conference*, 2014, Columbus, Ohio.
94. O. Pierrakos, E. M. Barrella, R. L. Nagel, J. K. Nagel, J. J. Henriques, D. D. Imholte, An Innovative Two-Year Engineering Design Capstone Experience at James Madison University, *120th ASEE Annual Conference and Exposition*, June 2013, Atlanta, Georgia.
95. O. Pierrakos, E. Pappas, R. Nagel, J. Nagel, A New Vision for Undergraduate Engineering Design Education: An Innovative Design Course Sequence at James Madison University, *ASEE Annual Conference and Exposition*, June 2012, San Antonio, Texas.
96. O. Pierrakos, R. Nagel, E. Pappas, J. Nagel, T. Moran, E. Barrella, M. Panizo, "A Mixed-Methods Study of Cognitive and Affective Learning During a Sophomore Design Problem-based Service Learning Experience," *International Journal for Service Learning in Engineering*, Special Edition, 2013, pp. 1–28. ISSN 1555-9033.
97. O. Pierrakos, Building Strong Academic Mindsets Focusing on Grit, Mastery Orientation, Belonging, and Self-Efficacy via an Effort Contingent Learning Environment in a Senior Engineering Capstone Design Course, *Capstone Design Conference*, June 2016, Columbus, Ohio.
98. W. S. Grolnick and R. M. Ryan, Autonomy in children's learning: An experimental and individual difference investigation, *Journal of Personality and Social Psychology*, **52**(5), 1987, p. 890.
99. A. L. Duckworth and P. D. Quinn, Development and validation of the Short Grit Scale (GRIT–S), *Journal of Personality Assessment*, **91**(2), 2009, pp. 166–174.
100. A. L. Duckworth, C. Peterson, M. D. Matthews and D. R. Kelly, Grit: perseverance and passion for long-term goals, *Journal of Personality and Social Psychology*, **92**(6), 2007, p. 1087.
101. S. J. Finney, S. L. Pieper and K. E. Barron, Examining the psychometric properties of the Achievement Goal Questionnaire in a general academic context, *Educational and Psychological Measurement*, **64**(2), 2004, pp. 365–382.
102. L. Claes, H. Vertommen and N. Braspenning, Psychometric properties of the Dickman impulsivity inventory, *Personality and Individual Differences*, **29**(1), 2000, pp. 27–35.
103. S. Eysenck and H. J. Eysenck, Impulsiveness and venturesomeness: Their position in a dimensional system of personality description, *Psychological Reports*, **43**(3f), 1978, pp. 1247–1255.
104. K. A. Bollen and R. H. Hoyle, Perceived cohesion: A conceptual and empirical examination, *Social Forces*, **69**(2), 1990, pp. 479–504.
105. A. Bandura, *Self-efficacy*. John Wiley and Sons. 1994.
106. S. B. Morris, Estimating Effect Sizes From Pretest-Posttest-Control Group Designs, *Organizational Research Methods*, **11**(2), 2008, pp. 364–386.

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