Paper ID #19515

Exploring the Relationship between Mindfulness and Innovation in Engineering Students

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The focus of Mark's research can broadly be described as "pivot thinking," the cognitive aptitudes and abilities that encourage innovation, and the tension between design engineering and business management cognitive styles. To encourage these thinking patterns in young engineers, Mark has developed a Scenario Based Learning curriculum that attempts to blend core engineering concepts with selected business ideas. Mark is also researches empathy and mindfulness and its impact on gender participation in engineering education. He is a Lecturer in the School of Engineering at Stanford University and teaches the course ME310x Product Management and ME305 Statistics for Design Researchers.

Mark has extensive background in consumer products management, having managed more than 50 consumer driven businesses over a 25-year career with The Procter & Gamble Company. In 2005, he joined Intuit, Inc. as Senior Vice President and Chief Marketing Officer and initiated a number of consumer package goods marketing best practices, introduced the use of competitive response modeling and "on-the-fly" A|B testing program to qualify software improvements.

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At Stanford she has served a chair of the faculty senate, and recently served as Associate Vice Provost for Graduate Education.

Exploring the relationship between mindfulness and innovation in engineering students

Abstract

An open, receptive, and curious (mindful) mindset is often cited as important in innovation. Yet, engineering education typically focuses on narrow analytical training at the expense of fostering expansive thinking. To specifically explore the relationship between a mindful attitude (open, receptive, curious) and innovation, we examined the relationship between dispositional mindfulness and innovation self-efficacy in a sample of 1,460 engineering students and recent graduates who completed the Engineering Majors Survey. Using social cognitive theory to frame our analysis, we found that a mindful attitude is correlated with innovation self-efficacy and that students with a highly mindful attitude tend to participate in learning experiences related to design and innovation. These results lay the groundwork for how mindfulness may promote foundational skills for successful entrepreneurship such as innovation, learning, and motivation.

1.0 Introduction

Engineering challenges are increasingly complex and demand innovative, collaborative solutions (Sheppard, Macatangay, Colby, & Sullivan, 2009). However, engineering education typically focuses on narrow analytical training at the expense of fostering important skills in creative thinking (e.g., questioning, observation, reflection) that are fundamental to developing innovative solutions to these engineering challenges. To help address this gap, there is an increasing number of studies exploring the pathways by which engineering students develop interest and skills in innovation (e.g. Yasuhara, Lande, Chen, Sheppard, & Atman, 2012; Davis & Amelink, 2016; Gilmartin et al., 2017). These studies aim to understand where students are gaining innovation interests and skills and are finding that extracurricular activities play a notable role. Within engineering classrooms, there is a push to increase student exposure to design and to teach creative thinking skills for innovative problem-solving (Daly, Mosyjowski, & Seifert, 2014).

Successfully gaining the creative thinking skills needed for innovation may rely on an open and receptive mindset (George & Zhou, 2001). This mindset is a key component of mindfulness, defined by Shapiro & Carlson (2017) as "*intentionally paying attention with kindness, openness and discernment*" (p. 4). Although psychologists are still trying to understand the exact mechanisms by which mindfulness facilitates innovation, there is convincing evidence that there is a causal link between a mindful attitude and creative innovative achievement (Lebuda, Zabelina, & Karwowski, 2016). By exploring the role of mindfulness and innovation among engineering students, we can begin to understand where a mindful attitude is beneficial and how we might teach mindfulness in engineering education.

This study investigates the relationship of mindfulness and innovation in engineering undergraduate students and recent graduates, answering the broad question: *how is mindfulness related to engineering innovation?* As a first step toward answering this question, we investigate the role of mindfulness in predicting the innovation self-efficacy of engineering students and recent graduates and we explore the characteristics of engineers with a highly mindful attitude.

2.0 Background

2.1 Operationalizing Mindfulness

We rely on the IAA model of mindfulness which posits that mindfulness has three core components: intention, attention, and attitude (IAA) (Shapiro, Carlson, Astin, & Freedman, 2006). Mindfulness is the process of *intentionally* paying *attention* moment by moment with an open, curious *attitude*. To employ a brief, multidimensional measure of mindfulness as part of a larger study of innovation, we chose a four-item measure of attention and a four-item measure of attitude. We measured mindful attention with the top four loading items of the Mindfulness Attention Awareness Scale (MAAS) (Brown & Ryan, 2003) in a sample of engineering undergraduates (Rieken, Schar, & Sheppard, 2016). For the mindful attitude items, we were interested in the tendency to maintain an attitude of receptivity towards one's experience. We chose to use the embracing sub-scale of the Curiosity and Exploration Inventory-II (CEI-II) which measures one's "*willingness to embrace the novel, uncertain and unpredictable nature of everyday life*" (Kashdan et al., 2009, p. 995).

2.2 Mindfulness and Innovation

For the purposes of this work, and the larger Engineering Majors Survey (EMS) project that the data stem from, we define innovation as "*encompassing skills, attributes, and actions relating to new designs and solutions that fundamentally depart from, and change thinking about, conventional practice*" (Gilmartin et al., 2017, p. 4). Based on the work by Dyer et. al., the EMS draws on five behaviors to assess innovation: questioning, observing, experimenting, idea networking and associative thinking (Dyer, Gregersen, & Christensen, 2008).

Innovation requires creativity to generate novel ideas. Dyer et. al. describe creativity as connecting things (associative thinking) in a novel way; individuals can become more creative by engaging in questioning, observing, experimenting and idea networking behaviors so that they have broad experiences to draw from. Creative behaviors are influenced by an individual's mindset, and an open, mindful attitude is consistently linked with creativity. McCrae (1987) found that an individual's openness score was correlated with a battery of divergent thinking tests (measuring ability to generate ideas by exploring many possible solutions) and argued that openness is related to having a flexible cognitive style. A flexible cognitive style allows individuals to be receptive to different perspectives and in turn to have a broader range of experiences from which to draw from in creative problem-solving. Feist (1998) found that creative scientists, as measured by creativity tasks, were more open-minded than less creative scientists. In group settings, openness has been shown to contribute to creative behavior in organizations (George & Zhou, 2001) and to creative performance in graduate student teams (Schilpzand, Herold, & Shalley, 2011).

An open-minded attitude has also been studied in the context of innovation and entrepreneurship more broadly. As part of a larger study of entrepreneurial intent in students, openness was shown to correlate with "intention to innovate" in a sample of undergraduate students and in a sample of MBA students (Mayhew, Simonoff, Baumol, Selznick, & Vassallo, 2016). In the work setting, a meta-analytical review found that entrepreneurs scored higher than managers on openness (Zhao

& Seibert, 2006). Our study differentiates and expands upon these results by looking at the respective relationships between 'mindful attention' and innovation and 'mindful attitude' and innovation among engineering students and recent engineering graduates.

2.3 Framework for Analysis: Social Cognitive Theory

The selection of variables for this study, and part of the larger framework of the EMS, was guided by Bandura's Social Cognitive Theory indicating that three determinants, *personal attributes*, *environmental factors,* and *behavior*, interact with triadic reciprocal causation (Bandura, 1986). These three determinants all operate bi-directionally on each other, meaning that there is no one direction of causality but rather a dynamic feedback loop, as seen in Figure 1.

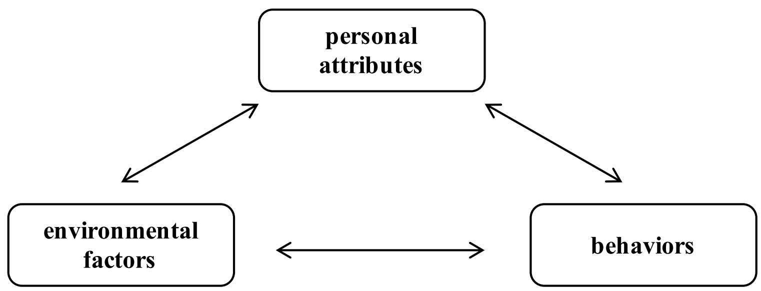


Figure 1. Bandura's triadic reciprocal causation.

We use social cognitive theory to explore the relationship between mindfulness and innovation, focusing on innovation self-efficacy as a gateway to innovative behaviors and goals. Both mindfulness and innovation self-efficacy are personal attributes in this model and interact with other personal attributes (e.g., gender and ethnicity), environmental factors (e.g., socioeconomic status and first generation status) and behavior (e.g., entrepreneurship and innovation focused learning experiences). Perceived self-efficacy is defined by Bandura (1986) as "*a judgment of one's capability to accomplish a certain level of performance*" (p. 391). Self-efficacy is central to agency; it affects motivation and behavior and therefore is an important factor in looking at any domain, including innovation.

In this study, we are only capturing a snapshot of a dynamic relationship between personal attributes, environmental factors, and behavior. We are interested in the relationship between the respondents' dispositional mindfulness (personal attribute), innovation self-efficacy (personal attribute), and learning experiences (behavior); and we recognize that there are many dynamic factors at play in shaping these relationships. We cannot make causal inferences but we can identify which variables may be associated with each other and study the relative strengths of these relationships.

2.4 Research Questions

This paper investigates the relationship of mindfulness and innovation in engineering students, answering the research questions: (RQ1) *Does a mindful attitude predict innovation self-efficacy?* (RQ2) *How do the backgrounds, learning experiences and career interests of engineering respondents with high mindful attitude scores compare to engineering respondents with low mindful attitude scores?*

3.0 Methodology

3.1 Survey Instrument

Data for this study come from the first and second administrations of the Engineering Majors Survey (EMS), an instrument designed as part of a longitudinal study of engineering students' interests and career goals surrounding innovation and entrepreneurship (Gilmartin et al., 2017). The first administration, the EMS 1.0, occurred in 2015 and had 7,197 respondents in the final analysis sample. The second administration, the EMS 2.0, was sent out to the EMS 1.0 respondents one year later in 2016 and had 1,460 respondents in the final analysis sample. For this study, we used demographic and learning experience data from the EMS 1.0 and openness and innovation-related data from the EMS 2.0. The following sub-sections identify the EMS measures used in this study; details and psychometrics of these measures can be found in (Gilmartin et al., 2017). A full list of survey items used in this study is included in the Appendix.

3.1.1 Measuring Mindful Attention

To measure the *mindful attention* component of mindfulness, we used four items drawn from a larger 15-item Mindfulness Attention Awareness Scale (MAAS) (Brown & Ryan, 2003). The MAAS measures mindfulness with a single factor structure, defining mindfulness as "*enhanced attention to and awareness of current experience or present reality*". Respondents indicate the frequency of their experiences on each item on a six-point Likert-type scale from 1="Almost always" to 6="Almost never". The MAAS items are reverse scored prior to data analysis so that a higher score indicates a higher level of dispositional mindful attention. To condense the MAAS to four items, we completed a factor analysis of MAAS pilot data with 68 undergraduate engineering students (Rieken et al., 2016). The variable "mindful attention" is created by averaging the four MAAS items for each respondent. The mindful attention items are only on the EMS 2.0 survey.

3.1.2 Measuring Mindful Attitude

To measure mindful attitude, we chose to use a collection of four items from the Curiosity and Exploration Inventory-II (CEI-II) (Kashdan et al., 2009). The four items represent the top four loading items of the five-item "embracing" subscale of the CEI-II, measuring "*a willingness to embrace the novel, uncertain, and unpredictable nature of everyday life*" (p. 955). Respondents indicate how they "generally feel and behave" on each item on a five-point Likert-type scale from 1="Very slightly or not at all" to 5="Extremely". The variable "mindful attitude" is created by averaging the four CEI-II items for each respondent. The mindful attitude items are only on the EMS 2.0 survey.

3.1.3 Measuring Innovation Self-Efficacy (ISE) and Engineering Task Self-Efficacy (ETSE)

We measure both Innovation Self-Efficacy (ISE) and Engineering Task Self-Efficacy (ETSE) in the EMS. All self-efficacy items were measured on a 5-point Likert-type scale from 0="Not confident" to 4="Extremely confident" (note that this scale is anchored at 0 for cross-comparison with other EMS studies). ISE measures one's confidence in their ability to innovate and consists of 5-items (Schar, Gilmartin, Rieken, Harris, & Sheppard, 2017; Gilmartin et al., 2017); each item measures one of the five innovative behavior domains identified by Dyer et. al (Dyer et al., 2008). This study uses the 5-item measure of ISE from the EMS 2.0, furthermore referred to as "ISE.5.2". We also included a 5-item measure of ETSE in this study as a reference for general self-confidence in integral technical engineering tasks as compared to ISE. This study uses the ETSE measure from the EMS 2.0, furthermore referred to as "ETSE.2".

3.1.4 Measuring Learning Experiences

The EMS asks current students to indicate if they have participated in 39 different learning experiences. For this study, we used the learning experience variables for each respondent as indicated EMS 1.0. Respondents who were still students at the time of the EMS 2.0 most likely participated in additional learning experiences in the year between the EMS 1.0 and the EMS 2.0; this detail will be incorporated in future work. Most of the activities on the EMS are related to innovation and entrepreneurship with a few more general engineering learning experience items such as participating in research or study abroad. There are 8 items asking about high school experiences; 4 items asking about co-curricular college activities; 7 items asking about college curricular experiences; and 20 items asking about extra-curricular college activities. The learning experiences give us an indication of behaviors in the social cognitive framework.

3.1.5 Measuring Career Intent

To gain some indication of the respondents' future interest in engaging with innovation through entrepreneurship, we included the EMS 2.0 items asking about the likelihood of pursuing various career options in the first five years after they graduate (for current students) or in the next five years (for non-students). The following careers options were given: "*work as an employee for a small business or start-up company*", "*work as an employee for a medium- or large-size business*", "*work as an employee for a non-profit organization (excluding a school or college/university)*", "*work as an employee for the government, military, or public agency (excluding a school or college/university)*", "*work as a teacher or educational professional in a K-12 school*", "*work as a faculty member or educational professional in a college or university*", "*found or start your own for-profit organization*", and "*found or start your own non-profit organization*." Items were measured on a 5-point Likert-type scale from 0="Definitely not" to 4="Definitely Will" (note that this scale is anchored at 0 for cross-comparison with other EMS studies).

3.2 Research Sample

The sample is composed of 1,460 survey respondents, mostly senior engineering students and engineers in their first year of work post-graduation from 27 different engineering schools. Table 1 reports the demographic characteristics of the sample. The respondents were 36.7% women, 12% underrepresented minorities (URMs), and 8.8% first generation college students.

Table 1: Demographic Characteristics of Students (N=1460)

Characteristic	n	%
Gender		
Male	925	63.3
Female	535	36.7
Student Status		
Current Bachelor's	958	65.6
Post-Bachelor's	502	34.4
Ethnicity		
Non-URM	1285	88.0
URM*	175	12.0
First Generation**		
No	1331	91.2
Yes	129	8.8

*URM=African American, Hispanic, Native American, & Pacific Islander.
**First Generation=Neither Mother nor Father Entered College

3.3 Data Analysis

Data analysis was completed in R (R Core Team, 2015). Data for the 1,460 respondents of the EMS 2.0 were merged with the corresponding demographic and learning experience data in the EMS 1.0 dataset. The resulting merged dataset was 98.1% complete with missing data missing completely at random. We used Multiple Imputation by Chained Equations (MICE) to impute missing values resulting in a 100% complete dataset (Buuren & Groothuis-Oudshoorn, 2011).

We first report descriptive statistics of the mindful attention and mindful attitude variables along with the correlation of these variables with Innovation Self-Efficacy (ISE.5.2) and Engineering Task Self-Efficacy (ETSE.2). Cohen's d was used to interpret the effect size of statistically significant gender differences in mindful attention and mindful attitude (using the standard convention of $0.2 < d < 0.5$ = small effect, $0.5 < d < 0.8$ = medium effect, $0.8 < d$ = large effect (Cohen, 1988)). The Pearson product-moment correlation coefficient (r) was used to report correlations with significance determined at the $p<.05$ level. We then used a multiple linear regression to predict ISE.5.2. We started with a complete pool of predictor variables that consisted of demographic variables (gender, URM-status, and first generation status), learning experiences (39 items), mindful attention and mindful attitude. To simplify the regression, a subset of predictor variables was selected using a forward and backward stepwise selection process to find the smallest Akaike information criterion (AIC) value. We used the stepAIC function in the MASS package for R. The final subset of data represents the least number of predictors with the highest value of R^2.

To examine descriptive differences between respondents with high mindful attitude scores and low mindful attitude scores, we created a "high mindful attitude" data subset (top quartile, n=434, mindful attitude >= 3.75) and a "low mindful attitude" data subset (bottom quartile, n=438, mindful attitude <=2.50). We used a chi-square for equality of proportions to test differences in demographic proportions and activity participation rates between the "high mindful attitude" and "low mindful attitude" groups. We used Cohen's *d* to interpret the effect size of statistically significant differences in career intent.

4.0 Findings

We found a significant relationship between mindful attitude and innovation self-efficacy across our sample. In addition, respondents with high mindful attitude scores tended to have taken undergraduate courses in design and business topics, to have participated in design- and business-related extra-curricular activities, and to express intentions of working for or founding a small business or start-up. The next sections detail these findings.

4.1 Mindfulness Descriptives

Tables 2-4 report descriptive and correlative statistics for the mindfulness variables, mindful attention and mindful attitude. Means, standard deviations and alpha coefficients are reported in Table 2. Both the mindful attention and mindful attitude variables had good internal consistency (α=.88 and α=.83 respectively). Mindful attention was measured on a scale from 1-6 and had a mean value of 4.20, slightly higher than seen in the full 15-item MAAS in other student populations (Rieken et al., 2016). Mindful attitude was measured on a scale from 1-5 and had a mean value of 3.12, similar to what is seen in other student populations (Kashdan et al., 2009).

Table 2: Means, Standard Deviations and Cronbach-α of Mindfulness Variables (N=1460)

Variable	M	SD	α
Mindful Attention	4.20	0.99	.88
Mindful Attitude	3.12	0.90	.83

Note: ATTN on scale from 1-6; OPEN on a scale from 1-5.

Table 3 shows the mindful attention and mindful attitude variables by gender. Although there was a significant difference in mindful attention between men and women, the effect size was small, and below threshold for a "small effect" when interpreting the Cohen's *d* value (M_{men} = 4.24, M_{women} = 4.12, p = 0.02, d = 0.12) (Table 3). We also see a significant difference in mindful attitude with an effect size slightly above the threshold for a "small effect", with men reporting higher scores of mindful attitude (M_{men} = 3.19, M_{women} = 2.99, p = .00, d = 0.22).

Table 3: Means, SDs, p-values, and Cohen's d values of Mindfulness Variables by Gender

	Men (n=925)		Women (n=535)			
	M	SD	M	SD	*p*	*d*
Mindful Attention	4.24	1.01	4.12	0.96	.02	.12
Mindful Attitude	3.19	0.89	2.99	0.91	.00	**.22***

*.2 < *d* < .5, small effect size

Table 4 shows that the mindful attention and mindful attitude variables did not correlate with each other in our sample. One can imagine having mindful attention without a mindful attitude or being an open, curious person without always paying attention to the present moment. Mindful attention correlated slightly with both Innovation Self-Efficacy (r =.13) and Engineering Task Self Efficacy (r =.11). Mindful attitude correlated more strongly with Innovation Self-Efficacy (*r*=.45) and Engineering Task Self Efficacy (*r*=.30). These results are not surprising as open-mindedness is often correlated with academic performance (Poropat, 2009). However, it is notable that mindful attitude more strongly correlated with innovation self-efficacy, indicating a stronger domain specific link between a mindful attitude and innovation than a mindful attitude and traditional engineering.

Table 4: Intercorrelations for Attention, Attitude and Self-Efficacy Variables

	1	2	3
1. Mindful Attention	–		
2. Mindful Attitude	-.03	–	
3. ISE.5.2	**.13****	**.45****	–
4. ETSE.2	**.11****	**.30****	**.66****

*p<.05. **p<.01.

4.2 Mindfulness as a Predictor of Innovation Self-Efficacy

RQ1: *Does a mindful attitude predict innovation self-efficacy?*

We used multiple regression analysis to examine the relationship between Innovation Self-Efficacy (ISE.5.2) and various potential predictors based on Bandura's theory of self-efficacy (personal attributes, environmental factors, and behaviors). As mentioned in the data analysis section, we used a forward and backward stepwise selection process to find the subset of predictors with the highest value of R^2.

Given the connection between open-mindedness and creativity in literature and the strong correlation between mindful attitude and ISE.5.2 in our data, we anticipated that mindful attitude would be a predictor of innovation self-efficacy. As can be seen in Table 5, the reduced multiple regression model had 14 predictors and produced an adjusted R^2=0.27 ($p < .000$). Mindful attitude was the strongest predictor (β=.41) of ISE.5.2 in the model, indicating that respondents reporting higher levels of mindful attitude were predicted to report higher levels of innovation self-efficacy after controlling for other variables. Mindful attention was also a predictor (β=.13) of innovation self-efficacy, with less weight than mindful attitude. Twelve learning experiences remained in the reduced model. Prior to controlling for mindful attention and mindful attitude, the learning experiences in the reduced model explained about 11% of the variance in ISE.5.2; adding mindful attention and mindful attitude increased the adjusted R^2 by fully 16%. (The adjusted r-square of the learning-experience-only reduced model is consistent with Schar et. al's (2017) model of ISE.5 using the EMS 1.0 data.)

Table 5: Regression Analysis Summary for Reduced Set of Personal, Environmental and Behavior Variables Predicting Innovation Self-Efficacy (ISE)

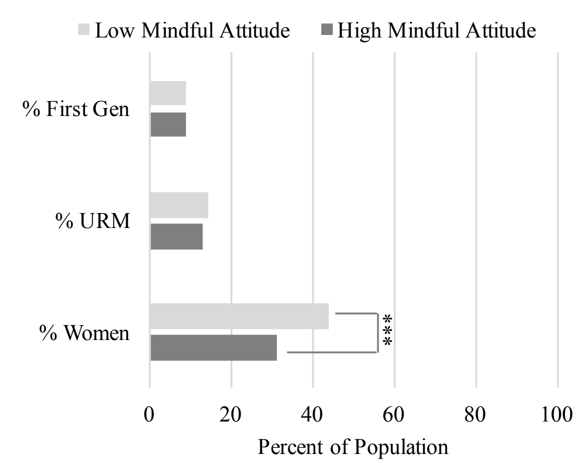
Variable	*β*	*SE*	*t*	*p*
Mindful Attention	.13	.02	5.70	.000***
Mindful Attitude	.41	.02	17.63	.000***
HS: Shop Class	.05	.02	2.34	.019*
HS: Robotics	-.05	.02	-2.39	.017*
HS: Started a Club	.07	.02	2.85	.004**
Internship	.07	.02	3.04	.002**
Course: Arts	.05	.02	2.24	.025*
Course: Theory of Design	.06	.03	2.33	.020*
Course: Designing/Prototyping	.04	.03	1.63	.103
Course: Leadership	.07	.02	2.80	.005**
Course: Business/Enterprise	.03	.02	1.43	.152
Engineering Club	.04	.02	1.72	.086
Used Maker Space	.05	.02	2.07	.038*
Start FP or Non-P Org	.04	.02	1.82	.069
Adjusted R^2	**.27**			
n = 1460, *β* and *SE* – standardized				

*p<.05. **p<.01. ***p<.001.

4.3 Comparison of Respondents with High Mindful Attitude and Low Mindful Attitude

RQ2*: How do the backgrounds, learning experiences and career interests of engineering respondents with high mindful attitude scores compare to engineering respondents with low mindful attitude scores?*

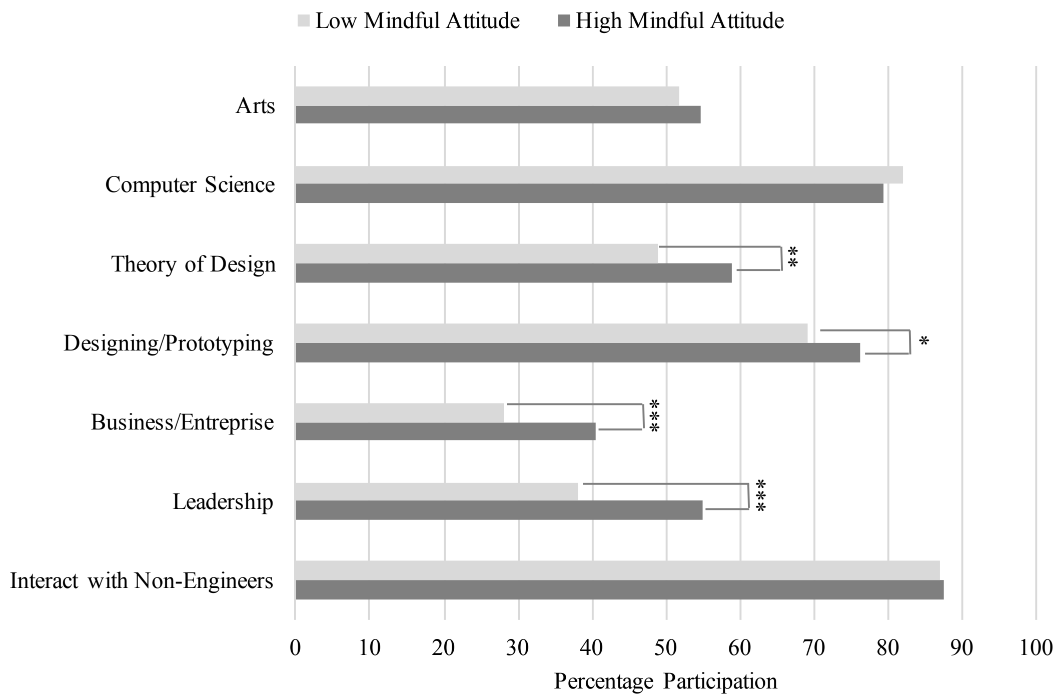
Given the strength of the relationship between mindful attitude and innovation self-efficacy, we explored the background and experiences of respondents with the highest mindful attitude scores and students with the lowest mindful attitude scores. Figure 2 shows demographic information about the high mindful attitude and low mindful attitude groups. There was no difference in the percentage of URM and first generation college students in the high mindful attitude and low mindful attitude groups. There was a significant difference in the gender breakdown of the groups; the high mindful attitude group was 31.3% women and the low mindful attitude group was 43.8% women (compared to 36.7% women in the overall population).



***p<.001; chi-square test for equality of proportions

Figure 2. Demographics of Respondents with High and Low Mindful Attitude

We then looked at the undergraduate course experiences of high mindful attitude and low mindful attitude respondents. As seen in Figure 3, respondents with high mindful attitude were more likely to have taken an undergraduate course that included "*theory of design*", "*designing and/or prototyping things or ideas*", "*business or enterprise topics (including entrepreneurship or venture creation)*", or "*leadership topics*" than students with low mindful attitude. However, there was no statistical difference between the groups in taking courses related to "*art, dance, music, theater, or creative writing*", "*computer science*" or "*interaction with students from non-engineering majors*".

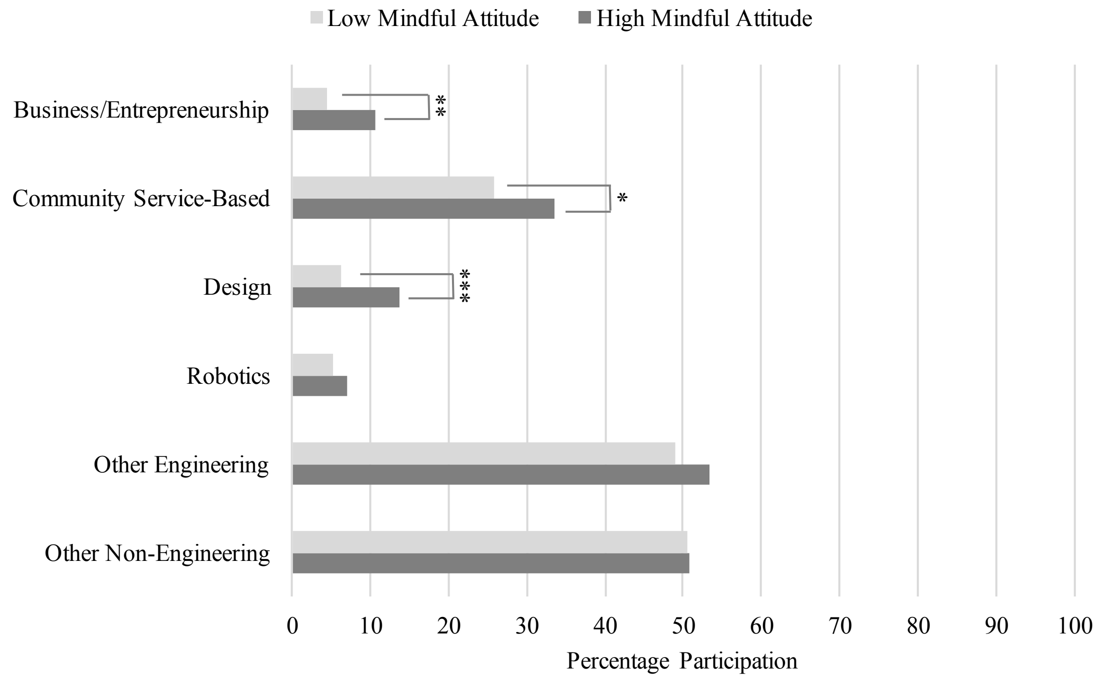


*p<.05. **p<.01. ***p<.001; chi-square test for equality of proportions

Figure 3. Undergraduate Course Topics of Respondents with High and Low Mindful Attitude

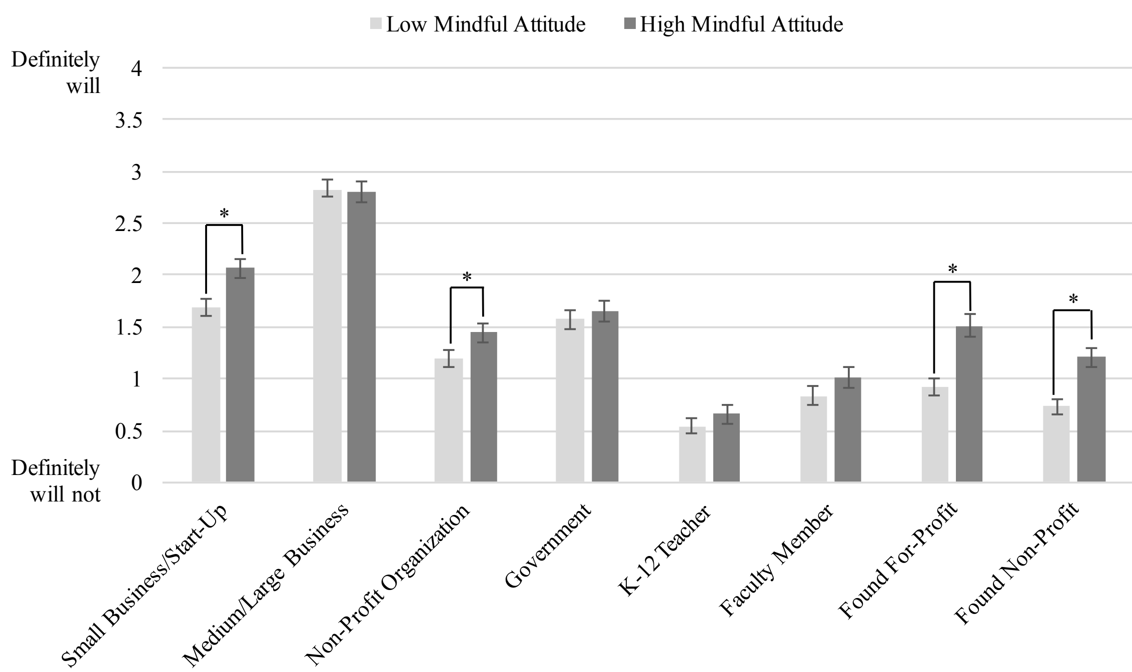
Similarly, we looked at extra-curricular club participation of high mindful attitude and low mindful attitude students. Figure 4 shows that respondents with high mindful attitude were more likely to have participated in a "*business or entrepreneurship club*", "*community service-base club (e.g. Engineers Without Borders, Design for America, EPICS)*" or a "*design club*". There was no statistical difference between the groups in their participation in a "*robotics club*", "*other student clubs or groups in engineering*" or "*other student clubs or groups outside of engineering*."

Lastly, we were interested in the career intent of high mindful attitude and low mindful attitude respondents. Figure 5 shows that respondents in both groups reported similar levels of intent to "*work as an employee for a medium- or large-size business*", "*work as an employee for the government, military, or public agency (excluding a school or college/university)*", "*work as a teacher or educational professional in a K-12 school*" or "*work as a faculty member or educational professional in a college or university*". In contrast, students with high mindful attitude were more likely to indicate intent to "*work as an employee for a small business or start-up company*", "*work as an employee for a non-profit organization (excluding a school or* *college/university)*", "*found or start your own for-profit organization*" or "*found or start your own non-profit organization*."



*p<.05. **p<.01. ***p<.001.; chi-square test for equality of proportions

Figure 4. Extra-Curricular Club Participation of Respondents with High and Low Mindful Attitude



*.2 < d < .5; Cohen's d effect size of difference in two means

Figure 5. Career Intent of Respondents with High and Low Mindful Attitude

5.0 Discussion

This empirical research study demonstrated a significant relationship between mindful attitude and innovation self-efficacy in our respondents, where mindful attitude is defined in this study as a willingness to embrace the novel, uncertain, and unpredictable nature of everyday life. We found that students who report a higher mindful attitude score have higher self-efficacy in both innovation self-efficacy (ISE) and in technical engineering task self-efficacy (ETSE); the data also evidenced a stronger relationship between mindful attitude and ISE (r=.45) than between mindful attitude and ETSE (r=.30).

A surprising finding was that female respondents tended to report lower scores of mindful attitude than did their male counterparts. In comparing this result to the literature, there is not a clear trend. Studies using the CEI scale generally do not report a difference between men and women (Kashdan, Rose, & Fincham, 2004). However, studies of the personality trait openness have shown that women report higher levels of openness to feelings and men report higher levels of openness to ideas (Costa Jr., Terracciano, & McCrae, 2001). The items in this work are ambiguous in their relation to ideas or feelings. A more nuanced survey instrument is needed to probe an open attitude at this granularity.

Data from this study show that mindful attitude is significantly correlated to participation in courses and activities related to innovation and entrepreneurship (e.g. courses in venture creation and design clubs). Further work is needed to establish if a mindful attitude supports future success in innovation and entrepreneurial endeavors.

Not only do we see a relationship between a mindful attitude and innovation self-efficacy, we also see a relationship between a mindful attitude and broader skills needed to bring innovative ideas into the marketplace through entrepreneurship. Respondents with high mindful attitude scores were more likely to have been involved in entrepreneurship clubs and courses that included business and leadership topics and are more likely to have plans to found an organization. Yasuhara *et. al*. found that extracurricular opportunities can bolster professional skills relevant to entrepreneurship by providing context for real engineering problems and by helping them develop a tolerance for ambiguity (Yasuhara et al., 2012); it could be that extracurricular activities, particularly those related to design, innovation and entrepreneurship, are the key to teaching and fostering an open mindset in engineering students.

6.0 Conclusion & Implications for Future Research

This research has important implications for engineering education, and entrepreneurial education more broadly. Specifically, it helps explain how a key component of mindfulness, a mindful attitude, may be connected to innovation self-efficacy, participating in entrepreneurship and design-related learning experiences, and intent to start a business or organization.

Future research could benefit by exploring if mindfulness training can cultivate a receptive, curious attitude toward new ideas and processes. Educating students on the benefits of a mindful attitude and offering specific instruction in mindfulness training could be one way to begin to shift students' mindsets. Broadening engineering education with contemplative education elements could also help to foster more open, aware and receptive engineers that in turn are more able to engage in innovative thinking. Under the umbrella of contemplative education elements, mindfulness practices promote a receptive, non-judgmental attitude and can be incorporated into the classroom (Barbezat & Bush, 2014). The preliminary findings of our study suggest that studying the impact of mindfulness training in engineering education warrants further research.

Collectively, these results lay the initial groundwork for understanding how mindfulness is related to the development of key entrepreneurial skills and learning behaviors. With a better understanding of the pathways and experiences of engineering students with these traits, we can begin to understand the benefits of mindfulness to engineering and start to explore what types of interventions might be useful in fostering mindfulness more broadly in the engineering student community.

7.0 Acknowledgments

The EMS study was conducted with support from the National Center for Engineering Pathways to Innovation (Epicenter), a center funded by the National Science Foundation (grant number DUE-1125457) and directed by Stanford University and VentureWell, formerly the National Collegiate Inventors and Innovators Alliance (NCIIA). The EMS research continues with funding support from the National Science Foundation (grant number 1636442).

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Appendix

4-items from Mindfulness Attention Awareness Scale (mindful attention)
EMS 2.0

Below is a collection of statements about your everyday experience. Using the scale below, please indicate how frequently or infrequently you currently have each experience. Please answer according to what really reflects your experience rather than what you think your experience should be.

Almost never (1)	Very Infrequently (2)	Somewhat infrequently (3)	Somewhat frequently (4)	Very frequently (5)	Almost Always (6)

It seems I am "running on automatic" without much awareness of what I am doing.
I rush through activities without being really attentive to them.
I do jobs or tasks automatically, without being aware of what I'm doing.
I find myself doing things without paying attention.

4-items from Curiosity and Exploration Index-II (mindful attitude)
EMS 2.0

Rate the statements below for how accurately they reflect the way you generally feel and behave. Do not rate what you think you should do, or wish you do, or things you no longer do. Please be as honest as possible.

Very slightly or not at all (1)	A little (2)	Moderately (3)	Quite a bit (4)	Extremely (5)

I am the type of person who really enjoys the uncertainty of everyday life.
Everywhere I go, I am out looking for new things or experiences.
I prefer jobs that are excitingly unpredictable.
I am the kind of person who embraces unfamiliar people, events, and places.

Innovation Self-Efficacy Scale (ISE.5.2)
EMS 2.0

How confident are you in your ability to do each of the following at this time?

Not Confident (0)	Slightly Confident (1)	Moderately Confident (2)	Very Confident (3)	Extremely Confident (4)

Ask a lot of questions
Generate new ideas by observing the world
Experiment as a way to understand how things work
Build a large network of contacts with whom you can interact to get ideas for new products or services
Connect concepts and ideas that appear, at first glance, to be unconnected

Engineering Task Self-Efficacy Scale (ETSE.2)
EMS 2.0

How confident are you in your ability to do each of the following at this time?

Not Confident (0)	Slightly Confident (1)	Moderately Confident (2)	Very Confident (3)	Extremely Confident (4)

Design a new product or project to meet specified requirements
Conduct experiments, build prototypes, or construct mathematical models to develop or evaluate a design
Develop and integrate component sub-systems to build a complete system or product
Analyze the operation or functional performance of a complete system
Troubleshoot a failure of a technical component or system

Career Intent
EMS 2.0

How likely is it that you will do each of the following {in the first FIVE YEARS after you graduate} or {in the next FIVE YEARS}?

Definitely will not (0)	Probably will not (1)	Might or might not (2)	Probably will (3)	Definitely will (4)

Work as an employee for a small business or start-up company
Work as an employee for a medium- or large-size business
Work as an employee for a non-profit organization (excluding a school or college/university)
Work as an employee for the government, military, or public agency (excluding a school or college/university)
Work as a teacher or educational professional in a K-12 school
Work as a faculty member or educational professional in a college or university
Found or start your own for-profit organization
Found or start your own non-profit organization

Learning Experiences
EMS 1.0

No (0)	Yes (1)

During high school, did you:
Take an art, dance, music, theater, or creative writing class
Learn computer programming
Take a shop class (e.g., a woodworking, automotive, or maker class) or engineering class
Participate in a robotics competition, such as a FIRST Robotics Competition
Attend a science, math, technology, or engineering related summer camp
Have a research position or internship at a science, math, technology, or engineering related company or organization
Learn about entrepreneurship
Start or co-found your own club, organization, or company

While an undergraduate, have you done (or are you currently doing) each of the following for at least one full academic or summer term?
Conduct research with a faculty member
Work in a professional engineering environment as an intern/co-op
Have a work-study or other type of job to help pay for your college education
Participate in study abroad

As part of your undergraduate coursework so far (including courses you are currently taking), have you taken courses that include any of the following topics or components?
Art, dance, music, theater, or creative writing
Computer science
Theory of design
Designing and/or prototyping things or ideas
Business or enterprise topics (including entrepreneurship or venture creation)
Leadership topics
Interaction with students from non-engineering majors

Below are various extra- and co-curricular activities you may have been involved in while an undergraduate. Many of these have to do with innovation and/or entrepreneurship; others are more general to the college experience. Please mark which of the following you have done during your undergraduate years so far (including activities you are currently doing).
Participated in a business or entrepreneurship club
Participated in a community service-based club (e.g., Engineers Without Borders, Design for America, EPICS)
Participated in a design club
Participated in a robotics club
Participated in other student clubs or groups in engineering
Participated in other student clubs or groups outside of engineering

Entered a business plan, business model, or elevator pitch competition
Entered a design or invention competition
Entered a social entrepreneurship/social innovation competition (e.g., the Dell Social Innovation Challenge)
Made use of a maker space/design or inventors studio/prototyping lab
Attended a career related event or meeting (e.g., a college career fair, a one-on-one meeting with a career counselor)
Attended a speaker series or related presentations about entrepreneurship and/or innovation
Attended a start-up bootcamp (e.g., Start-up Weekend, 3-Day Startup)
Attended a presentation on a new engineering technology, process, or design (outside of class)
Lived in a residential or dorm-based engineering program/engineering living-learning community
Lived in a residential or dorm-based entrepreneurship or innovation program/entrepreneurship or innovation living learning community
Received funding from a program to finance new ideas
Led a student organization
Started or co-founded a student club or other student group on campus
Started or co-founded your own for-profit or non-profit organization