Trait Mindfulness in an Engineering Classroom

An exploration of the relationship between mindfulness, academic skills, and professional skills

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Abstract— **This research explores the intersection of mindfulness and engineering education. Among the reported benefits of mindfulness are enhanced cognitive flexibility, improved concentration, and increased emotional intelligence. These characteristics may be beneficial to engineers as they tackle increasingly complex and interdisciplinary challenges. This research looks at trait mindfulness of 75 students in an introductory engineering course. Results show that mindfulness correlates with business skills self-efficacy (including interpersonal skills) but not with mechanics self-efficacy or final grade. There is also a correlation between mindfulness and the intent to pursue a career in a small company or in an entrepreneurial start-up company. Implications of this research suggest that mindfulness-based classroom activities may help broaden the engineering education experience.**

Keywords—mindfulness, mechanics self-efficacy, business self-efficacy, career intent, MAAS, CAMS-R

I. Introduction

Mindfulness has gained significant attention in both the popular press and in academic literature over the last decade. Among the reported benefits of mindfulness are enhanced cognitive flexibility, improved concentration, and increased emotional intelligence [1]. These characteristics may be beneficial to engineers as they tackle increasingly complex and interdisciplinary challenges. However, there is very little empirical literature about the relationship between mindfulness and engineering education. We are interested in answering the question: *Is trait mindfulness related to increased academic and professional skills performance among engineering students*? Through exploratory empirical research, we aim to discover the relationship, if any, between mindfulness, class performance, and future professional plans in an undergraduate engineering course.

II. Mindfulness

Mindfulness, as operationalized in this work, is a secular, psychological construct. We are guided by Jon Kabat-Zinn's definition of mindfulness, "paying attention in a particular way: on purpose, in the present moment, and non-judgmentally" [2]. There are three core components in this definition: *intention*, *attention*, and *attitude*. Mindfulness involves the *intention* to regulate attention, the action of sustaining *attention*, and an open, accepting *attitude* toward the experiences while paying attention [3].

Mindfulness is a capacity or *trait* that varies between individuals based on their willingness to devote attention to the present moment. Mindfulness training programs such as Kabat-Zinn's Mindful-Based Stress Reduction (MBSR) program [4], teach the cultivation of mindfulness. Achieving continual states of mindfulness through a program like MBSR leads to enhanced *trait* mindfulness, or a greater propensity to be mindful throughout the day when not actively practicing mindfulness exercises [5]. This research study measures *trait* mindfulness, which is defined as the existing, enduring mindfulness the student has at the time of completing the mindfulness instrument. We did not conduct any mindfulness training with the students.

The development of the MBSR program sparked many clinical studies on the effectiveness of mindfulness-based programs to treat various chronic illnesses and emotional and behavioral disorders [6]. This opened the door to what is now a fast growing research field looking at both the clinical applications of mindfulness-interventions and at basic scientific research questions around the neural and psychological mechanisms of mindfulness [7]. As our understanding of the basic science of mindfulness grows, there are more and more mindfulness training programs being developed for healthy populations. Mindfulness training has been shown to decrease stress and increase empathy among medical students [8] and is increasingly used in medical school curriculum. Mindfulness has also been introduced into classrooms ranging from kindergarten to higher education. In particular, contemplative practices such as mindfulness-based exercises are being used in higher education to increase student focus and attention and to promote student agency and a deepened understanding of course material [9].

III. Measuring Mindfulness

In order to do scholarly research on mindfulness in any context, we must have some way to measure an individual's mindfulness. Researchers in the field of psychology have developed psychometrically valid and reliable self-report survey instruments to measure trait mindfulness. The five most common instruments seen in mindfulness literature are the Mindful Attention Awareness Scale (MAAS) [10], the Freiburg Mindfulness Inventory (FMI) [11], the Kentucky Inventory of Mindfulness Skills (KIMS) [12], the Cognitive and Affective Mindfulness Scale - Revised (CAMS-R) [13], and the Five Factor Mindfulness Questionnaire (FFMQ) [14]. Each of these instruments are based on a particular conceptualization of mindfulness that ranges from a single construct to a five-faceted construct.

For the purposes of this study, we chose to use the MAAS and CAMS-R instruments due to their prominence in the literature and relatively short length (15- and 10-items respectively) compared to the FMI, KIMS, and FFMQ (30-, 39- and 39-items respectively) questionnaires. The MAAS operationalizes mindfulness as a single construct focused on the absence of attention to and awareness of present experience. It does not measure the non-judgmental attitude component of mindfulness. The CAMS-R is also a generic measure of mindfulness, however the authors conceptualized four aspects of mindfulness: attention, present-focus, awareness, and acceptance/non-judgment. The CAMS-R is scored as single total mindfulness score. For an in-depth comparison of published mindfulness instruments, see [15].

IV. Mindfulness and Engineering

There are clear cognitive and affective benefits of including mindfulness practices in higher education as outlined by Shapiro, Brown, and Astin [16]. Mindfulness may enhance cognitive skills such as monitoring and control of attention and critical thinking, or the ability to analyze and evaluate evidence and arguments [17]. Mindfulness may also enhance cognitive flexibility leading to more creative capacity [18]. Mindfulness may indirectly improve academic performance during high-stake tests by decreasing anxiety [19]. Beyond the cognitive benefits, mindfulness has been linked to higher interpersonal skills and engagement in empathy [20]. Mindfulness has also been shown to improve moral reasoning and ethical decision making [21].

Pursuing an engineering degree is often characterized as a high-cognitive-load, high-stress endeavor. Moreover, engineering students themselves are often characterized as having lower interpersonal skills and engagement in empathy than their humanities peers. For all these reasons, we aim to understand how mindfulness might impact the performance of engineering students specifically. We hypothesize that higher trait mindfulness is related to increased self-efficacy in both engineering and professional skills, mediated by increased self-regulation of attention and emotion. We are also interested in the relationship between mindfulness and future professional plans. We hypothesize that higher trait mindfulness is related to a desire to work in a smaller, more innovative environment, mediated by higher interpersonal and creative skills.

V. Research Questions

We are interested in answering the question: *Is trait mindfulness related to increased academic and professional skills performance among engineering students*? To begin to address this broad question, we focused on three specific research questions in this study:

RQ1: Are engineering students representative of the general population on self-report mindfulness instruments like the MAAS and CAMS-R?

RQ2: Do engineering students who score highly on the MAAS and CAMS-R mindfulness instruments have higher self-efficacy in mechanics skills and professional skills compared to lower mindfulness scoring engineering students?

RQ3: Are there any differences in career intent between higher mindfulness scoring and lower mindfulness scoring engineering students?

These research questions are part of a larger agenda to understand the potential benefits of mindfulness in educating well-rounded engineers with enhanced critical thinking skills and the ability to thoughtfully and creatively solve our most complex, sociotechnical, interdisciplinary problems.

VI. Methods

A. Research Sample

Participants were undergraduates at a private, Western US university enrolled in a one-quarter Introduction to Solid Mechanics course in the Fall of 2015. Of the 75 students who received a final grade in the course, 85.7% (n=64) were sophomores and juniors intending to major in engineering. Demographics relevant to the analysis in this paper are presented in Table I.

TABLE 1. Demographic Characteristics of Students (N=75)

Characteristic	n	%
Gender		
Male	44	58.6
Female	27	36.0
Other	1	1.3
Did not answer	3	4.0
Ethnicity		
White	27	36.0
Asian	19	25.3
URM*	23	30.6
Prefer/Did not answer	6	8.0
First Generation**		
Yes	5	6.7
No	67	89.3
Did not answer	3	4.0

*URM=African American, Hispanic, Native American, & Pacific Islander.

**First Generation=Neither Mother nor Father Entered College

B. Measures

The students completed a pre-course survey (n=72) during the first week of the course, a post-course survey (n=71) during the last week of the course and received a final grade in the course (N=75). For this study, we used demographic data from the pre-course survey and the final grade given by the professor. Data for all other measures are from the post-course survey.

1) MAAS

The Mindful Attention Awareness Scale (MAAS) is a 15-item instrument with a single factor structure indirectly measuring mindfulness by measuring the absence of attention and awareness of present experience [10]. Respondents indicate the frequency of their experiences using a 6-point Likert-type scale from 1 (*almost always*) to 6 (*almost never*). Items include, "*I rush through activities without being really* *attentive to them*," and "*I tend to walk quickly where I am going without paying attention to what I experience along the way*." The scale showed good internal reliability (α = .82). The full instrument is in the Appendix.

2) CAMS-R

We used the 10-item Cognitive and Affective Mindfulness Scale – Revised (CAMS-R) instrument. CAMS-R is a generic measure of mindfulness that includes items about attention, present-focus, awareness, and acceptance/non-judgment of daily experience [13]. Respondents indicate the frequency of their experiences using a 4-point Likert-type scale from 1 (*rarely/not at all*) to 4 (*almost always*). Items include "*It is easy for me to concentrate on what I am doing*," and "*I try to notice my thoughts without judging them*." The scale showed good internal reliability (α = .77). The full instrument is in the Appendix.

3) Grade

The final course grade is a weighted average of the grades from three exams, six homework assignments and two group projects. Final scores ranged from 72 (72%) to 97 (97%) out of 100 points.

4) Mechanics Self-Efficacy (MSE)

Students were asked about their confidence in their ability to complete four mechanics-related tasks: "*draw a free-body diagram*", "*write the equations of equilibrium of a system*", "*carry out the problem-solving process to analyze a system*", and "*overall, the skill and knowledge needed to complete all of the above tasks*". Answers ranged from 1 (*totally unsure*) to 6 (*definitely sure*). These items were developed for a previous study and are based on specific skills taught in the Introduction to Solid Mechanics course [22]. The four items had a high Cronbach's alpha (α = .84) and were averaged together to form a mean MSE score for each student.

5) Business Skills Self-Efficacy (BSSE)

Students were asked about their confidence to perform a series of business-related skills. The prompt was "*How confident are you in your ability to do each of the following at this time?*" followed by eight items scored from 1 (*not confident*) to 5 (*extremely confident*). The eight-items asked about recognizing a good idea, financing a new business, selecting a marketing approach, negotiating prices with a supplier, estimating the cost of a project, leading a team of people, communicating ideas, and promoting accomplishments. The items were adapted from a venturing and technology self-efficacy instrument [23] and have previously been used with engineering students in this course [24]. The students had some exposure to business-type demands through course projects. The eight items had a high Cronbach's alpha (α = .89) and were averaged together to form a mean BSSE score for each student. In addition, we used two of the eight items as stand-alone variables: "*communicate my ideas effectively to people in different positions or fields*" (BSSE-communicate) and "*lead a team of people*" (BSSE-lead). These two items give an indication of interpersonal self-efficacy.

6) Closeness to Others in Classroom

As a measure of student ability to build self-efficacy through interaction with other students, we also used the Aron Inclusion of Other in the Self (IOS) Scale [25]. We refer to this construct as "closeness." Students are presented with a series of Venn-like pictograms that show the relationship of "self" to "other" with the circles becoming increasingly overlapped from left (1) to right (5). The post-course survey included six "other" categories*: professor, TA, project team, closest friend in class,* and *pod* (assigned seating in clusters for the duration of the class). The six items had a high Cronbach's alpha (α = .80) and were averaged together to form a mean "closeness" score for each student. Further detail about the application of the Aron IOS Scale in this engineering classroom can be found in [26].

7) Career Intent

Students were asked about their future employment plans to assess career intent. The prompt was "*Looking into your future, over the 5 years from your graduation how likely are you to do any of the following?*". Students responded from 1 (*very unlikely*) to 5 (*very likely*) to six items, *work for a non-profit organization, work for a medium- or large-size US-based business, work as an employee for a small business or start-up company, work for the government or a public institution or agency, start my own business as an entrepreneur or be self-employed*, or *work for a large, multi-national global business*. The career intent items were adapted from the Engineering Majors Survey [27].

C. Data Analysis

The data analysis was done in R [28]. The Pearson product-moment correlation coefficient (*r*) was used to report correlations with significance determined at the $p < .05$ level.

VII. Results

RQ1. Are engineering students representative of the general population on self-report mindfulness instruments like the MAAS and CAMS-R?

Table 2 shows measured values of mindfulness (MAAS and CAMS-R). Mean mindfulness was not significantly different ($p>.50$ for all measures) between the overall population and any of the sub-populations. This is similar to results found in other studies of undergraduate populations [29].

Table 3 compares the mindfulness scores of the engineering students in this study to mindfulness scores in previous studies with nonclinical undergraduate populations. There is no significant difference in the self-reported mindfulness of the engineering undergraduates in our sample and other published self-report mindfulness scores in general undergraduate populations.

TABLE 2. MAAS and CAMS-R Mindfulness Scores

	MAAS		CAMS-R	
Population	M (SD)	95% CI	M (SD)	95% CI
Overall	3.85 (.65)	[3.70, 4.01]	2.70 (.65)	[2.58, 2.80]
Male	3.87 (.62)	[3.67, 4.08]	2.69 (.46)	[2.55, 2.84]
Female	3.81 (.68)	[3.53, 4.08]	2.62 (.36)	[2.46, 2.76]
URM	3.86 (.80)	[3.49, 4.23]	2.65 (.57)	[2.49, 2.81]
First Gen	4.04 (.72)	[3.15, 4.93]	2.96 (.67)	[2.13, 3.79]

TABLE 3. Mindfulness Scores Compared to Other Studies

MAAS					
Study	College Student Population	n	M	SD	p
This Study	Engineering	68	3.85	.65	
Brown 2003 [10]	Psychology	90	3.85	.68	1.00
MacKillop 2007 [29]	General	727	4.00	.85	.157
Shapiro 2008 [30]	General	29	3.60	.88	.124
Schmertz 2008 [31]	Psychology	50	3.70	.64	.215
Howell 2011 [32]	Psychology	427	3.87	.74	.833
CAMS-R					
Study	College Student Population	n	M	SD	p
This Study	Engineering	70	2.70	.45	
Feldman 2007 [13]	General	212	2.58	.52	.085
Schmertz 2008 [31]	Psychology	50	2.60	.33	.184

In looking toward using a mindfulness instrument in future research surveys, we performed a factor analysis on the 15-item MAAS confirming a single factor structure. The top four loading items (questions 7, 8, 10, and 14 (α=.79)) compare to the top four loading items found in other studies [29][33]. These four items (MAAS-4) showed a significant correlation with the entire MAAS 15-item set (r=.84, p=.00), as shown in Table 4.

RQ2: Do engineering students who score highly on the MAAS and CAMS-R mindfulness instruments have higher self-efficacy in mechanics skills and professional skills compared to lower mindfulness scoring engineering students?

Table 4 shows means, standard deviations, and correlations for mindfulness, self-efficacy, grade, and closeness measures. The MAAS and CAMS-R scores correlated significantly with a coefficient similar to what is seen in other publications (r = .49, p = .00) [14][13]. We hypothesized that higher mindfulness would correlate with higher MSE and final grade possibly mediated by increased attention regulation. We did not see this effect; mindfulness did not correlate with MSE (r = .07, p = .57) or final grade (r =-.03, p = .80). However, there is a significant, positive correlation between mindfulness and BSSE (r = .44, p = .00) indicating a possible relationship between mindfulness and professional business skills. In addition, both the BSSE-communicate (r = .37, p = .00) and BSSE-lead (r = .28, p = .02) variables within the BSSE measure positively correlated with mindfulness, indicating a possible relationship between mindfulness and interpersonal skills specifically.

One possible mediator of the relationship between mindfulness and BSSE is the "closeness" students feel to other students and teaching staff in the classroom, given the role of social processes in building self-efficacy [34]. We do see a significant positive correlation between mindfulness and closeness (r = .36, p = .00). Further work is needed to determine if the closeness variable plays a mediating role in the mindfulness and BSSE relationship and why this did not extend to MSE in this sample.

TABLE 4. Intercorrelations for Mindfulness Scores and Classroom Measures

	M (SD)	1	2	3	4	5	6	7	8
1. MAAS	3.85 (.65)	–							
2. MAAS-4	4.05 (.79)	**.84****	–						
3. CAMS-R	2.70 (.45)	**.49****	**.52****	–					
4. Final Grade	0.88 (.05)	-.03	-.05	-.12	–				
5. Mechanics SE	5.41 (.47)	.07	.07	.17	**.24***	–			
6. Business Skills SE	3.09 (.73)	**.44****	**.46****	**.44****	**-.28***	.16	–		
7. Communicate SE	3.80 (.84)	**.37****	**.36****	**.47****	-.18	.20	**.74****	–	
8. Lead SE	3.86 (.82)	**.28***	**.34****	**.30****	**-.35****	.14	**.69****	**.52****	–
9. Closeness	3.43 (.60)	**.36****	**.30****	**.26***	.12	.23	**.37****	**.44****	.22

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

It is also interesting to note that MSE positively correlates with final grade ($r = .24$, $p = .04$) while BSSE negatively correlates with final grade ($r = -.28$, $p = .02$). There is not a statistically significant relationship between MSE and BSSE ($r = .16$, $p = .18$).

RQ3: Are there any differences in career intent between higher mindfulness scoring and lower mindfulness scoring engineering students?

Table 5 shows the correlations for the MAAS and career intent. MAAS is positively correlated with intent to "*start my own business as an entrepreneur or be self-employed*" ($r = .24$, $p = .05$) and to "*work as an employee for a small business or start-up company*," ($r = .24$, $p = .05$) perhaps indicating some positive relationship between mindfulness and small group working environments.

TABLE 5. Intercorrelations for Mindfulness Scores and Career Intent

	1	2	3	4	5	6
1. MAAS	–					
2. Non-Profit Org	.17	–				
3. Government Inst	.20	**.37***	–			
4. Entrepreneur	**.24***	.16	.00	–		
5. Small Business	**.24***	-.04	- .06	**.41****	–	
6. M/L Business	.11	-.16	.00	**-.32****	.17	–
7. L Global Business	.07	**-.23***	.12	-.02	.23	**.51****

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

VIII. Discussion

Our first research question was to understand if published mindfulness instruments are useful in engineering classrooms. This study suggests that engineering students are representative of the general population of undergraduate students on self-report mindfulness instruments. This is useful to know for future work studying mindfulness in engineering student populations. Additionally, a 4-item instrument based on the full MAAS instrument yields comparable results to the full 15-item MAAS; an important finding for studies with a significant completion time constraint.

Our second research question surrounded the relationship between mindfulness and self-efficacy in technical and professional skills. Surprisingly, mindfulness was not correlated with MSE or final course grade. Given that previous research has shown a link between mindfulness and increased attention-regulation and critical thinking [17], we expected that students with higher trait mindfulness would have higher confidence in the technical course concepts and perform better in the course. This could indicate that mindfulness is not related to learning introductory technical concepts. It could also indicate that there is a more nuanced relationship that was not uncovered in our dataset. Would concentration-based mindfulness exercises encourage students with high trait mindfulness to apply their capacity for attention-control in the classroom? Exercises could include a short breath-focused meditation or active listening activities. Further research is needed to probe this question.

Even more surprising is that mindfulness is correlated with BSSE which is *negatively* related to final course grade as depicted in Fig. 1. This suggests that students with higher interpersonal and professional business skills might be scoring lower in introductory analytic courses. This is somewhat alarming in that it might send a message to these types of students that they don't belong in engineering even though they bring essential skills to the engineering community. In fact, up to 75% of engineers graduate into a for-profit business environment [35]; we should be aiming to retain engineering students with high BSSE. Further investigation of this relationship is needed.

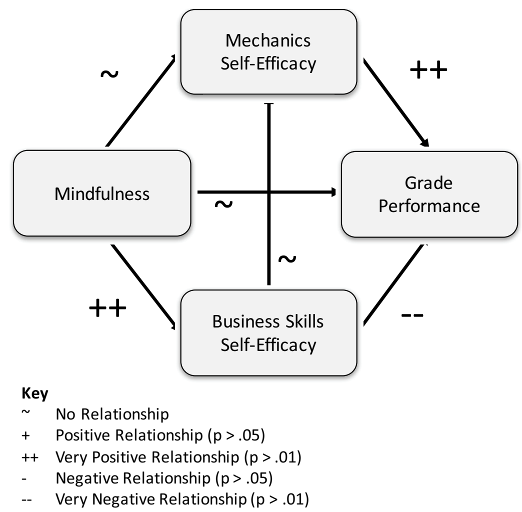

Figure 1. Relationship between mindfulness, MSE, BSSE, and final grade.

In our third research question, we were interested in the relationship between mindfulness and future career plans, particularly in the desire to work in a start-up or small business environment. We found that students with higher levels of trait mindfulness have great intent to work in a start-up or small business. This may be related to our previous finding that mindfulness is correlated with BSSE. There are many possible factors that might mediate the link between mindfulness and a desire to work in small business environment. One possibility is that working in a small, tight-knit environment appeals to students with stronger interpersonal and empathy skills, both of which are associated with higher trait mindfulness [20][8][36]. Another possibility is that students with higher trait mindfulness have enhanced creativity behavior [18] and desire a broader, hybrid engineering and business career. All of these relationships would need to be explored in greater depth than available in this study.

IX. Conclusion

Mindfulness scores in this student engineering population are representative of mindfulness scores reported in general undergraduate populations. Mindfulness correlates with business skills self-efficacy (including interpersonal skills) but not with mechanics self-efficacy or final grade. This could indicate that the cognitive benefits of mindfulness are not those that are assessed in an introductory engineering course. It could also mean that mindfulness is not necessary for success in technical engineering tasks (but most likely beneficial in more complex sociotechnical work associated with most professional engineering jobs). There is also a correlation between mindfulness and the intent to pursue a career in a start-up or small business environment.

This is an exploratory study that begins to address the question: *Is trait mindfulness related to increased academic and professional skills performance among engineering students*? The data from this study raise many questions. Why is there no link between mindfulness and classroom performance (grade) despite improved attention and self-regulation associated with higher levels of trait mindfulness? What are the mediating variables linking mindfulness with business skills self-efficacy and intent to pursue a career in a small business or start-up environment?

We recognize that the findings from this work come from a very specific group of students and are not necessarily generalizable to larger engineering populations. We are excited to expand this exploration to more diverse populations of engineering students. We also recognize that one of the limitations of using the single-score MAAS and CAMS-R mindfulness instruments is that we only have information about the present awareness facet of the mindfulness construct. In future studies, when it is possible to use a longer questionnaire, we would like to use the FFMQ to examine the interaction of the various facets of mindfulness with our outcome variables.

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APPENDIX

Mindfulness Attention Awareness Scale:

Below is a collection of statements about your everyday experience. Using the 1-6 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. Please treat each item separately from every other item.

1	2	3	4	5	6
Almost Always	Very Frequently	Somewhat Frequently	Somewhat Infrequently	Very Infrequently	Almost Never

1. I could be experiencing some emotion and not be conscious of it until some time later.
2. I break or spill things because of carelessness, not paying attention, or thinking of something else.
3. I find it difficult to stay focused on what's happening in the present.
4. I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.
5. I tend not to notice feelings of physical tension or discomfort until they really grab my attention.
6. I forget a person's name almost as soon as I've been told it for the first time.
7. It seems I am "running on automatic," without much awareness of what I'm doing.
8. I rush through activities without being really attentive to them.
9. I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.
10. I do jobs or tasks automatically, without being aware of what I'm doing.
11. I find myself listening to someone with one ear, doing something else at the same time.
12. I drive places on "automatic pilot" and then wonder why I went there.
13. I find myself preoccupied with the future or the past.
14. I find myself doing things without paying attention.
15. I snack without being aware that I'm eating.

Cognitive and Affective Mindfulness Scale – Revised:

1	2	3	4
Rarely/Not at all	Sometimes	Often	Almost Always

1. It is easy for me to concentrate on what I am doing.
2. I can tolerate emotional pain.
3. I can accept things I cannot change.
4. I can usually describe how I feel at the moment in considerable detail.
5. I am easily distracted. (R)
6. It’s easy for me to keep track of my thoughts and feelings.
7. I try to notice my thoughts without judging them.
8. I am able to accept the thoughts and feelings I have.
9. I am able to focus on the present moment.
10. I am able to pay close attention to one thing for a long period of time.

(R) = reverse score