Inner engineering: Evaluating the utility of mindfulness training to cultivate intrapersonal and interpersonal competencies among first-year engineering students

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Abstract

Background: There is clear consensus among influential education reports that an expansive range of intrapersonal (e.g., self-regulation) and interpersonal competencies (e.g., empathy) highly influence educational and career success. Research on teaching and learning these competencies is limited in engineering education.

Purpose/Hypothesis: This study explores the impacts of a mindfulness training program on first-year engineering students and aims to understand potential impacts on the development of intrapersonal and interpersonal competencies.

Design/Method: A four-session mindfulness-based program was designed, developed, and facilitated to cultivate intrapersonal and interpersonal competencies. Qualitative data were collected from a total of 35 students through a post-survey (n = 32), 3-month follow-up survey (n = 24), and interviews (n = 18). A thematic analysis process accompanied by validity and trustworthiness checks was employed to analyze the data.

Results: The results suggest that the majority of students became more mindful, which led to improved intrapersonal competencies (e.g., self-regulation, focus, resilience, and well-being) and interpersonal competencies (e.g., empathy, communication, teamwork, and leadership).

Discussion/Conclusions: The study provides compelling evidence that mindfulness training can support the development of intrapersonal and interpersonal competencies among engineering students, which can support their overall academic experience, personal, and professional development. Future design and development work will be needed to evaluate the integration and scalability potential of mindfulness training within engineering programs.

Keywords

first-year experience, mindfulness, professional skills, reflective practice, student development
1 | INTRODUCTION

There is a growing recognition that intrapersonal and interpersonal competencies play an important role in the future success of engineering students. Several influential reports have suggested that efforts must be made to develop and assess these competencies (Clough, 2005; Lucas et al., 2014; National Academies of Sciences, Engineering, and Medicine, 2017; National Research Council [NRC], 2012; K. Prince et al., 2015). For example, the NRC of the National Academies report on Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century examined the role of these competencies for success in the 21st century within education, work, health, and life contexts (NRC, 2012). The report generated a taxonomy (summarized in Table 1) of three broad domains—cognitive, intrapersonal, and interpersonal—and provided a brief definition for each domain:

The cognitive domain involves reasoning and memory; the intrapersonal domain involves the capacity to manage one's behavior and emotions to achieve one's goals (including learning goals); and the interpersonal domain involves expressing ideas and interpreting and responding to the message from others. (p. 3)

Cognitive competencies—such as problem-solving (e.g., Kirn & Benson, 2018), critical-thinking (e.g., Ralston & Bays, 2015), information literacy (e.g., Wertz et al., 2013), and creativity (e.g., Cropley & Cropley, 2000)—have been studied more extensively than intrapersonal and interpersonal competencies thus far (NRC, 2012). There have been influential reports (e.g., Clough, 2005; Lucas et al., 2014) that have highlighted the increasing importance of intrapersonal and interpersonal competencies to the future success of engineering students, including strong communication skills, professionalism, dynamism, agility, resilience, flexibility, desire for lifelong learning, and leadership. Other non-cognitive competencies such as resilience, reflection, and collaboration are not unique to engineering but nonetheless are instrumental to becoming a good engineer (Lucas et al., 2014). Research examining these domains supports this idea and further notes that intrapersonal and interpersonal competencies support deeper learning of school subjects (NRC, 2012).

The existing literature suggests that changes in technology and digital networks have led to a modern workplace where employees are increasingly collaborative, resilient, adaptable, and integrated with one another. Lappalainen (2009) notes that “engineers no longer manage their daily task with plain substance expertise; instead, they must be adept at communication, collaboration, networking, feedback provision and reception, teamwork, lifelong learning, and cultural understanding” (p. 123). This is particularly true for engineering leaders who perceive teamwork, personal development, and communication skills as more important to their professional work than technical or business management skills (Crumpton-Young et al., 2010). Such findings are not surprising when considering that engineers spend about 55%–60% of their day communicating as part of collaborative efforts (Passow & Passow, 2017). In the same study, problem-solving, teamwork, communication, planning and time management, taking initiative, thinking creatively, and focusing on goals were identified by practicing engineers, engineering faculty, and engineering graduates as the most important competencies needed to contribute to the future engineering workplace. The authors suggest that “technical competence is inseparably intertwined with effective collaboration” (p. 491).

The sum of the existing literature referencing intrapersonal and interpersonal competencies suggests an emerging consensus within the engineering ecosystem that such competencies are important in the engineering profession. This consensus has not translated into engineering education, which has traditionally focused on developing technical skills and largely neglected developing a more holistic skillset (Clough, 2005). The result is practicing engineers who lack the professional skills needed in the workplace (Ragsdell, 2000). The following sections highlight the existing efforts in

| Competencies     | Definition                                                                 | Examples                                      |
|------------------|----------------------------------------------------------------------------|-----------------------------------------------|
| Cognitive        | Involves cognitive processes and strategies including reasoning and memory | Knowledge, creativity, innovation, critical-thinking, problem-solving |
| Intrapersonal    | The capacity to manage one’s behavior and emotions to achieve one’s goals | Intellectual openness, flexibility, adaptability, resilience, curiosity, self-regulation, metacognition |
| Interpersonal    | Involves expressing ideas and interpreting and responding to the messages of others | Teamwork, communication, leadership, listening, empathy |
engineering education to promote interpersonal and intrapersonal competencies and why there remains a need to further investigate new, innovative approaches to foster interpersonal and intrapersonal competencies among engineering students, particularly as technological advancements lead a shift in the skills necessary to contribute to the future workplace.

1.1 Need for interpersonal competencies

In the last two decades, there has been a shift in engineering education as a major emphasis has been placed on integrating active-learning pedagogies to develop a wider range of competencies. Active-learning pedagogies have largely been successful in enhancing lifelong learning, design, problem-solving, communication, and teamwork while also improving students’ awareness of societal and global issues, ethics, and professionalism (Lattuca et al., 2006). Additionally, active-based learning has been found to promote deeper learning (Krajcik et al., 1999), transfer of knowledge (Yadav et al., 2011), motivation (Jones et al., 2013), and student engagement (M. Prince, 2004; Smith et al., 2005).

While the proliferation of active, experiential learning pedagogies in engineering education has supported the development of interpersonal competencies such as communication and teamwork, additional evidence has indicated there is still room for improvement in developing these competencies among engineering students (Meier et al., 2000; Nair et al., 2009; Nguyen et al., 2005). For example, Nair et al. (2009) found the highest differences in attributes between recent graduates and employer expectations were oral communication skills, written communication skills, and interpersonal skills. Students have also been found to self-assess themselves lower on communication and presentation skills relative to their perceived importance in their future employment (Nguyen et al., 2005). These studies align with the competency gaps Meier et al. (2000) identified among STEM graduates, who suggested the need to extend traditional curricula to include a focus on listening and teamwork skills, sharing information and cooperating with coworkers, satisfying customer expectations, and adapting to changing work environments.

A number of studies highlight the complexity of successfully integrating active-based learning as this pedagogy places the onus on students to self-direct their own learning (e.g., Jones et al., 2013; M. Prince, 2004; Savage et al., 2007). One major limitation may be that engineering students are mostly expected to learn interpersonal and intrapersonal competencies incidentally without guidance. Many engineering educators possess an implicit assumption that empathy and other related affective dimensions are fixed traits and, therefore, not teachable nor learnable skills (Walther, Miller, & Sochacka, 2017). This notion was clearly delineated by Hess, Strobel, Pan, and Wachter Morris (2016) who found that engineering professionals scored particularly low on an item that stated, “I learned to be more empathetic and caring during my college years.” Engineers disagreeing that their college experiences promoted empathy and care, both important interpersonal competencies, coincides with findings that engineering students possess less empathetic concern than students from other disciplines like social work and psychology (Rasoal et al., 2012).

Empathy as an engineering skill has gained recognition in engineering education as an important interpersonal competency for engineering students to develop. Learning to be empathetic has a wide range of benefits including supporting teamwork and communication skills (Baron-Cohen, 2011), making ethical decisions (Hess et al., 2017), and influencing the design process (Gray et al., 2015; Leonard & Rayport, 1997; Vallero & Vesilind, 2006; Zoltowski et al., 2012). The existing literature provides little guidance on how to foster empathy in undergraduate engineering programs despite the benefits (Hess et al., 2017; Hess, Strobel, Pan, & Wachter Morris, 2016; Walther, Miller, & Sochacka, 2017). Several efforts to promote empathy have been developed (e.g., Hess et al., 2017; Walther et al., 2012). Other related efforts include a growing number of engineering leadership programs offered by engineering schools or professional organizations. However, according to Graham et al. (2009), “The majority of [leadership] programs appear to have no formal or articulated mechanisms to deliver the leadership component of this goal, beyond (typical) student involvement in project-or-problem-based learning activities,” limiting their effectiveness (p. 5). In the same study, many of the existing engineering leadership programs were found to simply string together preexisting modules from across the university and perhaps an additional team-based project at the end to tailor it to engineering students (Graham et al., 2009).

The existing literature implies that there is a need to further develop and investigate research-validated approaches for teaching interpersonal competencies to engineering students and explore how these can be more effectively integrated in engineering curricula. These can perhaps even augment the experiences students have within project-based learning classes (e.g., first-year design courses and senior capstone courses) that rely heavily on active-based pedagogies.
1.2 | Need for intrapersonal competencies

Research exploring the promotion and understanding of intrapersonal competencies within engineering education has included effort beliefs (e.g., Snyder et al., 2018), incremental beliefs about intelligence (e.g., Stump et al., 2014), self-regulated learning (e.g., Nelson et al., 2015), reflection (e.g., Turns et al., 2014), metacognition (e.g., Cunningham et al., 2015), emotional intelligence (Elegebe, 2015; Skipper & Brandenburg, 2013), emotional resilience (Jesiek et al., 2014), adaptability (Ahn et al., 2012), emotional awareness (Bish et al., 2014), working under pressure (Walther et al., 2011), empathy (Hess, Strobel, Pan, & Wachter Morris, 2016; Walther, Miller, & Sochacka, 2017), and mindfulness (Goldberg & Somerville, 2014). The sum of this literature suggests that possessing these intrapersonal competencies supports positive outcomes within an engineering context. For example, Snyder et al. (2018) found that first-year engineering students who scored higher on positive effort beliefs, that is, their efforts are useful and would lead to positive outcomes, were more likely to also have higher grade point averages. Intrapersonal competencies are critical in improving student engagement in active-learning strategies (Stump et al., 2014), avoiding maladaptive learning profiles (Nelson et al., 2015), and developing metacognitive (Vos & de Graaf, 2004) and self-regulatory skills (Cunningham et al., 2015).

Turns et al. (2014) suggest a need for more research emphasizing the impact of reflection activities in engineering education. Reflection is foundational to self-regulated learning, (Zimmerman, 1998a, 1998b, 2002), metacognition (Flavel, 1979; Pintrich, 2002; Tarricone, 2011), and deep learning (Van Meter et al., 2016). Recent studies suggest that engineering students and practitioners value reflection as a tool for slowing down and thinking for the purpose of improvement, meaning making, monitoring progress, and making decisions (Carberry et al., 2018; Csavina et al., 2017).

Several other engineering education researchers have strongly advocated for the integration of emotional intelligence in engineering education, which has been found to have a positive impact on leadership effectiveness, teamwork, and career success (Elegebe, 2015). Sunindijo et al. (2007) found that project managers and engineers with higher emotional intelligence correlated with higher self-reported open communication and proactive leadership styles. Lappalainen (2015) also found that socio-emotional intelligence correlated with successful leadership among engineering managers, while mathematical-logical intelligence demonstrated no correlation with subordinates’ perception of successful leadership. The available research exploring a variety of intrapersonal competencies demonstrates the immense value such competencies can have on student learning as well as supporting interpersonal competencies such as leadership and teamwork.

1.3 | Student mental health concerns

There are alarming statistics that suggest there is considerable room for improvement to develop intrapersonal competencies among engineering students. Many students, not just in engineering, struggle to find mental balance. In the National College Health Assessment (NCHA) of 79,266 students, 51.4% felt overwhelmed by all they had to do in the last 2 weeks, 27.6% felt overwhelming anxiety, 15.1% felt so depressed that it was difficult to function, and 33.2% reported stress negatively affecting their individual academic performance (American College Health Association, 2018). The rate of mental disorders such as anxiety and depression has been steadily increasing over the past 8 years (Center for Collegiate Mental Health, 2020). Beyond the health ramifications, stress and anxiety are strong predictors of poor academic performance (Storrie et al., 2010), including in engineering student populations (Vitasari et al., 2010). Engineering is well known to be an arduous major with considerable perceived stress among students (Cross & Jensen, 2018; Foster & Spencer, 2003; Schneider, 2007). Strong intrapersonal competencies, like self-regulation, can help students cope with stress in productive ways and to succeed in school.

A concerted effort is needed to continue to identify approaches to assist students in developing intrapersonal and interpersonal competencies to mitigate student mental health concerns, and not to allow stress to negatively impact their academic performance. This is especially vital in the first year when many students are making a major transition and may have added responsibilities and stressors (e.g., academic pressure, financial concerns, and relationship difficulties). Potential stress can lead to a feeling of being overwhelmed, which can drive students to migrate to other disciplines; the first-year retention rate of engineering students was 80% in 2014, whereas the four- and six-year graduate rates have been found to be over 30% and nearly 60%, respectively (Yoder, 2016).
1.4 | Purpose

This study explores cultivating mindfulness as a means of supporting the development of intrapersonal and interpersonal competencies among first-year engineering students. Mindfulness refers to one’s ability to maintain awareness at the present moment. There is an exponentially growing body of literature within psychology that has explored the benefits of mindfulness training, especially among college students (Brown et al., 2015; J. D. Creswell, 2017). Much of this initial exploration has centered around improving health outcomes (e.g., treating mental illness, chronic pain, etc.) (J. D. Creswell, 2017; Kabat-Zinn, 1982). Recent literature has begun to investigate mindfulness training as a tool to promote intrapersonal and interpersonal competencies among college students (Bamber & Schneider, 2016). There is potential for mindfulness to support some of the limitations that exist in engineering education in developing these competencies. Currently, no such studies have been conducted to explore the potential benefits of mindfulness training for engineering students. The purpose of this study is to investigate the potential utility of mindfulness to support the development of intrapersonal and interpersonal competencies among first-year engineering students.

2 | THEORETICAL FRAMEWORK

The concept of mindfulness is rooted in Buddhist psychology and has origins that can be traced back over 2500 years. It was only in the 1980–1990s that it became secularized and adopted by Western researchers (Brown et al., 2015). Although mindfulness has now been studied for several decades, no consensus conceptualization has emerged (vyo, 2014). Mindfulness is a complex phenomenon to understand because it is rooted in consciousness itself. Perhaps, the most influential definition of mindfulness is “paying attention in a particular way, on purpose, in the present moment, and non-judgmentally” (Kabat-Zinn, 1994, p. 4). Most operational definitions of mindfulness include the capacity of being attentive or aware of the immediate, present moment or experience and the adoption of an orientation marked by acceptance, non-judgment, curiosity, and openness (e.g., Baer et al., 2006; Bishop et al., 2004; Cardaciotto et al., 2008; Davis et al., 2009; Feldman et al., 2007). These attitudes support the capacity for one to maintain a clear awareness of their salient internal and external realities in any given moment. This is why mindfulness has been associated with having a “pure” or “lucid” awareness (Gunaratana, 1996). A common misconception is that mindfulness is antithetical to thought. Mindfulness instead allows the self to separate from thoughts and emotions to observe oneself objectively, which can elicit insight into one’s own biases and emotional response tendencies (Brown & Ryan, 2003). The rest of this section focuses on the psychological mechanisms of mindfulness proposed by Shapiro et al. (2006) and the connection to intrapersonal and interpersonal competencies. A visual of the overarching theoretical framework is summarized in Figure 1.

2.1 | Reperceiving

Shapiro et al. (2006) identified the meta-mechanism of mindfulness as reperceiving. Reperceiving describes the fundamental shift in perspective that occurs when one develops the capacity to orient oneself to the present moment and dispassionately (or objectively) observe the contents of consciousness (e.g., one’s thoughts, emotions, self-concepts, etc.). One perceives the content of consciousness, that is, thoughts and emotions, as “objects” within the field of awareness by “separating” oneself from these contents. One is no longer identified (or defined, determined, or controlled) by one’s own thoughts and emotions because they are distinct objects separate from the self (Kabat-Zinn, 1990). It is important to note that reperceiving is not the same as numbing one’s experience or becoming apathetic or disinterested (Shapiro et al., 2006). The opposite is true in that one can observe the experience within the present moment exactly how it is with intimacy versus identifying oneself with the mind’s subjective commentary of what is happening. Reperceiving is a natural process, but mindfulness practice is believed to accelerate this shift in perspective (Shapiro et al., 2006).

2.2 | Additional mechanisms

Reperceiving enables the other mechanisms of mindfulness to manifest, including (1) exposure; (2) self-regulation; (3) cognitive, emotional, and behavioral flexibility; and (4) values clarification (Shapiro et al., 2006). Exposure refers to the
ability for one to experience strong emotions with openness and less reactivity (Shapiro et al., 2006). Through reperceiving one can more readily “expose” oneself to information that was previously too difficult to carefully examine (Hölzel et al., 2011; Treanor, 2011). There is more tolerance to metacognitively observe unpleasant internal states instead of avoiding or denying them because they are too overwhelming or frightening (Farb et al., 2013; Hayes et al., 2006). Exposure can enable one to access more objective, reliable information (Sayers et al., 2015; Shapiro et al., 2006). The insights gained from observing unpleasant internal states can interrupt conditioned, maladaptive habits and behaviors (Bishop et al., 2004). One can more readily identify when they are ruminating, which is engaging in repetitive, obtrusive, unproductive thought-patterns (Nolen-Hoeksema et al., 2008; Trapnell & Campbell, 1999).

Reperceiving can thus enhance one’s self-regulatory skills. In this context, self-regulation refers to “the exercise of control over one’s self, especially with regard to bringing the self into line with preferred standards” (Vohs & Baumeister, 2004, p. 2). An increased capacity to tolerate, regulate, and more productively cope with negative emotions can eventually lead to the extinguishment of previous stressors and associated maladaptive habits (Arch & Landy, 2015; Farb et al., 2013; Garland & Howard, 2013; Roemer et al., 2015; Sayers et al., 2015; Vago & Nakamura, 2011). One can more readily disengage from default, conditioned reactions, which affords the opportunity to reappraise situations and choose a different, potentially adaptive response.

Reperceiving offers a buffer against immediate, automatic reactivity and allows psychological space to metacognitively reflect. This leads to the broadening of attention and allows for a more flexible selection of appraisals (Gable & Harmon-Jones, 2010; Garland et al., 2010; Schwabe & Wolf, 2009). Reperceiving, therefore, promotes cognitive, emotional, and behavioral flexibility (Shapiro et al., 2006), which generally refers to one’s ability to adapt or respond to situations flexibly in a constantly changing environment. This is in contrast to an inability to alter one’s behavioral strategy optimally for goal achievement due to acting in an overly rigid, reflexive manner.

Reperceiving is also thought to improve one’s capacity to recognize what one considers to be most important or personally meaningful (Shapiro et al., 2006). Values clarification refers to the “reflexive, personal, sociocultural, and intercultural processes whereby one seeks to identify the influential value priorities that guide one’s interests, choices, actions, and reactions in a variety of interpersonal and social contexts” (Kulich & Chi, 2014, p. 296). Values are instilled and conditioned by family, culture, and society, and one may not realize to what extent certain values actually drive one’s choices. Reperceiving can enable one to more objectively reflect on the values that drive one’s behavior including conditioned or reflexively adopted values. One can rediscover or consciously choose their values and set intentions to behave in a manner that is congruent with those values (Brown & Ryan, 2003; Shapiro et al., 2006).
2.3 Connection to intrapersonal and interpersonal competencies

Through the previously mentioned mechanisms, mindfulness can support the development of intrapersonal and interpersonal competencies. One has an enhanced ability to handle negative emotions, self-regulate, and act in accordance with their values with greater flexibility and conscious control. The mechanisms of mindfulness directly support the development of intrapersonal competencies, which explains why mindfulness has been found to promote affective constructs such as resilience, equanimity, and well-being (Brown & Ryan, 2003; Garland et al., 2015; Hayes et al., 2006).

Mindfulness may also be able to support learning through the mechanism of self-regulation, which is considered to be essential in developing lifelong learning skills that can increase student achievement and motivation (Schunk & Zimmerman, 1998). Self-regulated learners are proactive in their efforts to learn because they are guided by goals and task-related strategies. Such learners use metacognitive awareness, that is, awareness and knowledge of one's own thinking, to actively monitor and control their performance, including self-reflection on the effectiveness of their approach (Zimmerman, 2002). Mindfulness may support self-regulated learning by enhancing the quality of metacognitive awareness and helping one clarify their values and goals.

The connections between mindfulness and interpersonal competencies are less studied; however, mindfulness has been found to promote interpersonal competencies such as teamwork and leadership skills in work environments (Good et al., 2016), and in general support the quality of relationships and social interactions (Brown et al., 2007). Mindful awareness can also be used to mitigate misunderstandings or conflicts through enhanced perspective-taking (Barnes et al., 2007) and exhibiting less hostility or anger (Saavedra et al., 2010).

3 LITERATURE REVIEW

There is a growing body of evidence demonstrating the efficacy of mindfulness to support a range of cognitive, affective, and interpersonal benefits (Brown et al., 2015). Mindfulness is typically measured as a trait (e.g., trait mindfulness) or one's general mindfulness level over an extended period. It can also be measured as a state (e.g., state mindfulness) or one's mindfulness level within a narrow bandwidth of time. This study focused on evaluating changes to trait mindfulness.

Levels of trait mindfulness have been measured in populations through psychometric instruments. Several scales (e.g., the Mindfulness Attention Awareness Scale [MAAS] of Brown & Ryan, 2003; or the Five Facet Mindful Attention Scale [FFMQ] of Baer et al., 2006) have demonstrated reliability and validity with different subsets of populations, including college students (Baer et al., 2006), adults (Brown & Ryan, 2003), clinical populations (Baer et al., 2004), and experienced meditators (e.g., Chadwick et al., 2008). The use of these scales in mindfulness interventions has established that mindfulness can be cultivated through regular meditation and other contemplative practices, hence the term mindfulness meditation (J. D. Creswell, 2017; Quaglia et al., 2015).

Higher levels of mindfulness have been found to positively correlate with enhanced self-regulated functioning (Deci & Ryan, 1985; Roemer et al., 2015), higher levels of life satisfaction (Brown & Ryan, 2003), eudaimonic well-being (Hanley et al., 2015), conscientiousness (Giluk, 2009; Thompson & Waltz, 2007), autonomy (Brown & Ryan, 2003), optimism (Brown & Ryan, 2003), self-compassion (Chiesa et al., 2014), empathy (Birnie et al., 2010; Dekeyser et al., 2008; Shapiro et al., 1998), emotional intelligence (Schutte & Malouff, 2011), perspective-taking (Schutte et al., 2001), relationship satisfaction (Carson et al., 2004), and agreeableness (Thompson & Waltz, 2007). Mindfulness has also been found to negatively correlate with depression (Cash & Whittingham, 2010), neuroticism (Giluk, 2009), cognitive reactivity (Raes et al., 2009), social anxiety (Rasmussen & Pidgeon, 2011), rumination (Nolen-Hoeksema, 2000), difficulties in emotional regulation (Baer et al., 2006), experiential avoidance (Baer et al., 2004), and unpleasant emotional experiences (Baer et al., 2006; Broderick, 2005; Brown & Ryan, 2003).

3.1 Overview of mindfulness interventions

The first generation of mindfulness intervention studies primarily focused on treating adult patients in clinical settings. For example, the well-known Mindfulness-Based Stress Reduction (MSBR) program was designed and developed to help adults alleviate chronic pain (Kabat-Zinn, 1982). Mindfulness interventions have been applied to treat many
clinical symptoms such as anxiety, depression, chronic pain, immune system function, heart disease, substance abuse, and eating disorders (J. D. Creswell, 2017; Ludwig & Kabat-Zinn, 2008). The success of the MSBR program has led to the development of other mindfulness interventions with different areas of focus ranging from cognitive therapy to relapse prevention (e.g., Bowen et al., 2014; Teasdale et al., 2000) to relationship enhancement (e.g., Carson et al., 2004; Wachs & Cordova, 2007). Mindfulness interventions have been integrated over the past 10 years into a variety of institutional settings, including work environments (Good et al., 2016) and schools (Sibinga et al., 2016). Many organizations (e.g., Aetna, Google, Nike, Target, the U.S. Army, Goldman Sachs) offer mindfulness training to their employees to positively influence goal-directed behavior and buffer against stressors that disrupt productivity (Good et al., 2016). Mindfulness is theorized to enhance workplace functioning, such as enhanced workplace performance, relationships, and well-being (Good et al., 2016; West et al., 2014; Wolever et al., 2012).

There is now an abundance of meta-analysis papers that have surveyed numerous studies with the conclusion that mindfulness interventions lead to increased mindfulness levels and psychological benefits (e.g., Chiesa et al., 2014; J. D. Creswell, 2017; Gotink et al., 2015; Keng et al., 2011). The rigor of research on these interventions has improved and made quality evidence available for reference (J. D. Creswell, 2017). The use of randomized control trial (RCT) studies that use wait-listed (and even active-control groups) has increased substantially; however, many of these studies still are limited to small sample sizes (J. D. Creswell, 2017; Davidson & Kaszniak, 2015). For example, Jain et al. (2007) found that mindfulness meditation and somatic relaxation activities both decreased self-reported psychological distress, but only mindfulness meditation reduced rumination. Improvements in brain imaging have also provided evidence of the neurobiological pathways and mechanisms involved in mindfulness (Tang et al., 2015). Brain-imaging studies of mindfulness studies have shown more activity in the prefrontal cortex, anterior cingulate cortex, and insular cortex of participants. Less activity was seen in the amygdala, which leads to greater attentional control and ability to modulate the emotional regulation network (Fox et al., 2014; Hölzel et al., 2011; Wheeler et al., 2017). The overall findings suggest that attention takes less effort among mediators (Tang et al., 2015) and that fewer attentional resources are used to process distractions (Cahn & Polich, 2006).

### 3.2 Mindfulness interventions and college students

Mindfulness interventions have now been studied extensively among healthy college students. Bamber and Schneider (2016) recently completed a narrative synthesis of 57 mindfulness intervention studies on college students. Most of the studies revealed that students’ stress, anxiety, and depression decreased after participation in a mindfulness intervention. Additionally, many of these studies also demonstrated significant positive effects on well-being (e.g., Brown & Ryan, 2003; Shapiro et al., 1998), empathy (e.g., Birnie et al., 2010; Beddoe & Murphy, 2004), and compassion (e.g., Greeson et al., 2014). The most common program used by these studies was the 8-week MSBR program. There was also evidence that shorter mindfulness interventions were also effective although it remains unclear how many sessions are needed to increase mindfulness among college students (Bamber & Schneider, 2016). Most studies focused on general college student populations, but several studies focused on specific groups like law students (Danitz & Orsillo, 2014), nursing students (Beddoe & Murphy, 2004; Song & Lindquist, 2015), and student athletes (Goodman et al., 2014). J. D. Creswell’s (2017) meta-analysis concluded that RCT studies among healthy young adult samples demonstrate that mindfulness improves attention-related outcomes (e.g., sustained attention, working memory, problem-solving performance), and affective outcomes (e.g., reduced rumination). Mindfulness meditation has been shown to improve academic performance among students (Jha et al., 2007; Mrazek et al., 2013), and dispositional mindfulness has been found to be correlated with their adjustment to the university (Mettler et al., 2017).

### 3.3 Mindfulness and engineering

The overview of the theory and literature suggests that mindfulness can support a wide range of benefits among different populations, including the cultivation of intrapersonal and interpersonal competencies (e.g., self-regulation, resilience, well-being, and empathy). Little research has been conducted to date exploring the potential links between mindfulness and engineering. The first of these studies was conducted by Bernádez et al. (2014) using a quasi-experimental approach involving 32 software engineering and information systems students. Participants were divided
into two groups: one group practiced mindfulness and the other trained in public-speaking. The results following a four-week intervention revealed that the students who practiced mindfulness had become more efficient in developing conceptual models than the students who had attended public-speaking sessions.

Rieken and Schar (2017) recently explored the relationship dispositional mindfulness has with innovation and business-related skills (Rieken et al., 2016) for engineering students. This work revealed mindfulness to be significantly correlated with innovation self-efficacy, business skills self-efficacy (including interpersonal competencies), and the intent to pursue a career in a start-up or entrepreneurship. The most recent work in this space was conducted by Spanjian (2019) who used interviews of 10 practicing engineers working at a large, global manufacturing company to explore the self-perceived impact of a 6-week mindfulness training program. The results illustrate that mindfulness had a positive impact on engineers' productivity and quality of work by enhancing intrapersonal awareness and interpersonal effectiveness. Interviewers with participants described an enhanced ability to control their emotions and manage work-related stress. This included an ability to “pause” and reperceive a situation before immediately reacting emotionally, which led to improvements in their ability to manage the demand for their technical expertise and solve complex technical problems more methodically. The engineers also describe being more open-minded and willing to listen and understand the perspective or feedback of others, which allowed them to be less defensive over their technical decisions and more adept at managing competing interests among various stakeholders.

The limited available research connecting mindfulness to engineering outcomes provides reason to be optimistic that mindfulness may be able to develop intrapersonal and interpersonal competencies that transfer to engineering contexts. There are, however, no studies that have evaluated the potential benefits of mindfulness training in engineering education. This exploratory study sought to further investigate the connection between mindfulness training and the development of intrapersonal and interpersonal competencies that support students' engineering education experience. We explore this purpose by investigating the following research questions:

1. Can engineering students improve their mindfulness through a brief, four-session mindfulness intervention?
2. How does mindfulness training influence the development of intrapersonal and interpersonal competencies among engineering students?

It was hypothesized that students would experience an improvement in their mindfulness, which would lead to improvements in students' intrapersonal and interpersonal competencies. Since this was an exploratory study, it was less clear to what extent mindfulness training may influence specific intrapersonal and interpersonal competencies and how any changes would manifest within engineering education contexts.

4 | METHODS

There are many existing mindfulness-based interventions (MBI) that have been applied in different settings with different intended purposes. No MBIs were identified in the literature to have been specifically tailored toward a first-year engineering student population. A mindfulness program was designed and developed with the intention of cultivating intrapersonal and interpersonal competencies and conveying the importance of these skills to engineering academic and career success. The program, named the Inner Engineering Leadership Program, was marketed at one large, public southwest institution as an extracurricular program consisting of four workshops. The number of students treated for anxiety at this institution doubled between 2010 and 2018, going from 9.2% to 22.1% of students (American College Health Association, 2018).

The overarching study adopted a pragmatic worldview. Pragmatism is a research philosophy that focuses on a “what works” approach to collecting and analyzing data that address the research questions (J. W. Creswell & Clark, 2017). It supports the use of both quantitative and qualitative methods by embracing both singular and multiple realities. The study was originally designed as an explanatory mixed methods study (QUANT → QUAL) in which the qualitative data would explain the quantitative data (J. W. Creswell et al., 2003). This approach evolved into a multiphase mixed methods study (see Huerta, 2019, for full details on the methodology and triangulation of data) involving two phases of qualitative data collection and three quantitative surveys (pre-survey, post-survey, and 3-month delayed post-survey). This paper presents the qualitative phases occurring at multiple times following the final workshop.
The remainder of the methods section provides details on (1) researcher qualifications, (2) curricular influences, (3) program curriculum including major design and development decisions, (4) participant information, (5) qualitative data collection methods used, (6) data analysis processes, and (7) limitations. Process reliability and validity evidence are integrated throughout these subsections to illuminate potential influences on the study (Kellam & Cirell, 2018; Walther, Sochacka, et al., 2017).

### 4.1 Researcher qualifications

The primary researcher and workshop facilitator (first author) had 7 years of personal experience in practicing mindfulness prior to creating and facilitating the program. He acquired tacit knowledge on both Western and Eastern conceptualizations of mindfulness through reading best-selling books written by Jon Kabat-Zinn, Thich Naht Hanh, Sadhguru, Michael Singer, David Hawkins, and Alan Watts. Further knowledge was obtained to aid the creation and facilitation of the workshop through the completion of the MSBR program, a local Mindfulness Leadership Certificate Training program, and the Koru mindfulness teacher training. He then took a graduate-level course focused on mindfulness research and read through many notable mindfulness publications. Finally, the researcher consulted with a local center for mindfulness in developing the curriculum. All of these experiences prepared the facilitator to undertake the complex task of designing, developing, and facilitating a mindfulness program tailored toward engineering students.

### 4.2 Curricular influences

The Search Inside Yourself (SIY) and the Koru mindfulness programs had the most influence on the curricular design of the program. Lecture content and discussions were also influenced by the mindfulness literature and the researchers’ personal experience. The SIY program was developed by Chade-Meng Tan, a former Google engineer. Content for SIY is openly shared and discussed in his book titled *Search Inside Yourself: The Unexpected Path to Achieving Success, Happiness (and World Peace)* (Tan, 2014). The SIY program is a mindfulness leadership program designed from the perspective of an engineer to improve workplace performance. It takes a pragmatic, utilitarian approach and makes explicit connections between mindfulness and emotional intelligence, and work-related outcomes. The SIY also includes active listening and journal reflection activities. These activities and connections to emotional intelligence and work-related outcomes were integrated into the lectures and activities of the program. The Search Inside Yourself Leadership Institute (SIYLI) website claims >20,000 individuals have participated, and the program reports a 10% reduction in emotional drain, a 28% increase in ability to focus, and a 21% increase in ability to remain calm and poised during challenges (SIYLI, 2021).

The Koru program was developed and iterated at Duke University by two psychiatrists, Drs. Holly Rogers and Margaret Maytan. Koru is designed to teach mindfulness, meditation, and stress management to college students and other young adults. There are currently >300 certified Koru instructors who have applied the program to >50,000 students (Center for Koru Mindfulness, 2021). The facilitator was trained as a Koru mindfulness facilitator prior to designing the workshops. The structure of the program, that is, four weekly workshops, and meditations integrated in the program, were largely influenced by Koru’s program. Greeson et al. (2014) evaluated the effectiveness of Koru in an RCT featuring 90 students (66% female and 71% graduate students). The students in the experimental group exhibited statistically significant improvements in mindfulness, perceived stress, sleep problems, and self-compassion, whereas the waitlist control group did not show statistically significant improvements. The effect sizes (Cohen’s $d$) were large for changes in mindfulness and moderate for perceived stress, sleep problems, and self-compassion.

### 4.3 Design and development

Several key design decisions were made in developing the program based on evidence presented in the literature review on MBIs. It was decided early that the program would be offered to first-year engineering students as a 4-week extracurricular program composed of 1-h workshops. First-year engineering students were selected because they are an especially vulnerable population who are traditionally undergoing a major transition involving added responsibilities and stressors (e.g., academic pressure, financial concerns, and relationship difficulties) (Dyson & Renk, 2006). Available
Evidence suggests the median age-of-onset mental disorders range between late teens to early 20s (Kessler et al., 2007). This makes traditional first-year students, typically 18–19 years old, a logical group to support and provide with skills to cope with stress productively.

Eight weeks has been considered the standard for most programs (Goyal et al., 2014), but research has suggested that four sessions is the minimum time period to begin observing effects in MBIs (Broderick, 2005; Papies et al., 2015; Westbrook et al., 2013; Zeidan et al., 2011). This decision made the Koru program a better fit for this project over the Mindful-based Stressed Reduction Program (MBSR) because it has a 4-week structure with shorter meditations designed for college students. The 8-week MBSR program consisting of eight, 2.5-h workshops and a final 7-h, 1-day retreat was considered too time-intensive for engineering students, who have many competing interests and opportunities. The SIY program content (ideas and activities) was used to supplement the Koru meditations and enable students to draw connections among mindfulness, emotional intelligence, and practical academic and engineering-related outcomes (e.g., improving teamwork in engineering projects).

Lecture, experiential, and active-learning pedagogies were used to deliver the workshop content. The workshops were held in-person in the Fall of 2018, prior to the pandemic. Mindfulness theory and research evidence were introduced using a traditional lecture approach. Explicit connections were made on how mindfulness can be used to cultivate intrapersonal competencies (e.g., self-awareness and self-management) and interpersonal competencies (e.g., empathy, active listening, communication, teamwork, and leadership). A variety of activities were integrated throughout the four workshops to encourage active participation and practice. These activities included different guided meditations designed to induce state mindfulness, discussion (e.g., think–pair–shares and active-listening exercises), and reflection (e.g., journaling). A typical workshop lasted 60 min and consisted of 20 min of lecture, 15 min of meditation and discussion, and 25 min of discussion activities. Students were also encouraged to practice mindfulness on their own and gradually increase their practice over time.

The content of the four workshops were segmented and titled: (1) Mindfulness and Self-Awareness, (2) Mindfulness and Self-Management, (3) Mindfulness and Empathy, and (4) Mindfulness and Habit-Building. Table 2 provides an overview of each workshop. The first two workshops provided an overview of the program and focused on intrapersonal competencies. Students were introduced to the concepts of mindfulness, self-awareness, self-management, and meditation. Research evidence on mindfulness was briefly shared to provide credibility to the topic. A major emphasis of the first two workshops was encouraging students to practice cultivating state mindfulness more frequently on their own by taking a few minutes or moments each day to briefly focus their attention on internal phenomena, that is, thoughts, emotions, and sensations. Students were encouraged to objectively observe their everyday stressors and monitor their daily habits. An explicit connection was made to metacognitive monitoring and controlling of thoughts. Several think–pair–share activities were integrated in the first two workshops for students to begin thinking critically about the ideas of mindfulness, self-awareness, and the relationship to self-management in school and life. Students were also introduced to a 3-min, guided meditation designed to cultivate state mindfulness. The facilitator guided the students on focusing their attention on their breath, performing a quick body scan, and noticing one’s thoughts and feelings. This 3-min meditation was then used to start each of the following workshops. The first workshop also included a brief, deep-breathing exercise, while the second workshop included a body scan.

The objectives of the third and fourth workshops were to demonstrate the value of focusing one’s attention externally, especially toward others. The third workshop focused on the importance of empathy and mindful (active) listening and how these skills can be applied within the context of engineering design work. Students were encouraged

| Topic                        | Content                                                                 |
|------------------------------|-------------------------------------------------------------------------|
| 1. Mindfulness and self-awareness | Focus on intrapersonal competencies including mindfulness and connection to self-awareness, self-management, and meditation |
| 2. Mindfulness and self-management |                                                                 |
| 3. Mindfulness and empathy | Focus on interpersonal competencies including empathy, communication, teamwork, and leadership, and connection to mindfulness |
| 4. Mindfulness and habit-building | Focus on how mindfulness relates to building positive habits |
to try perspective-taking and to minimize judgment of others. An exercise with integrated think–pair–share discussions was included to allow students to practice empathy and active listening. A discussion followed regarding the exercise’s utility in their life, especially in developing teamwork and leadership skills. Students were encouraged to be conscientious in their daily interactions and notice the influence they have on others. The fourth workshop was dedicated to how mindfulness can be used to cultivate positive habits. The researcher guided the students on several activities (e.g., think–pair–shares and journal reflections) designed to have them reflect on their goals and daily habits. The group discussed how mindfulness can support positive learning habits. Students were also encouraged to immerse themselves fully with daily actions, such as walking and eating. Students practice this idea in the fourth workshop through an activity called “mindful eating,” which is designed to have students immerse themselves fully in the process of eating.

4.4 | Institutional context

The mindfulness-based program was offered as an extracurricular program to first-year engineering students at a large, R1 public southwest institution. In the Fall of 2018, 2476 first-year students enrolled in the college of engineering, and the first-year retention rate of these students was 89.1% (Arizona State University [ASU] Facts, 2020). The Fall 2015 four-year graduation rate was 46.6%, and the Fall 2013 six-year graduation rate was 68.6% (ASU Facts, 2020). First-year engineering students declare their major upon enrollment and are expected to enroll in engineering courses immediately, including taking a required 100-level introduction to engineering course. In 2019, the college of engineering had 590 engineering faculty and $115 M in research expenditures (ASU Facts, 2020).

4.5 | Recruitment and participants

The four workshop sessions were offered during the Fall 2018 semester at two campus locations. A variety of recruitment strategies were used. Researchers were not compensated by the institution for the creation of the program, but institutional support was provided to assist in participant recruitment. Flyers were distributed physically to first-year engineering dorms and electronically through listservs and engineering faculty who posted the flyer on their course learning management system (e.g., Blackboard or Canvas). Additionally, class presentations were also made to aid recruitment. Details on the program were provided along with a link to register.

The flyer described the program as a leadership program that will maximize the impact of their engineering education. A clear statement was made that students “will be introduced to techniques that foster resilience, leadership skills, and positive habit formation” and that they should expect to “learn to critically reflect on previous assumptions and beliefs, become comfortable with uncertainty and adversity, and allow space for creative solutions.” The flyer can be seen in Appendix A. The description was intentionally written to be ambiguous and does not explicitly use the term “mindfulness” to help mitigate self-selection bias.

To register for the program, students had to provide their consent to participate, select the date of the program(s) they would attend, and complete the pre-survey. A total of 148 students opened the registration link and provided their consent to participate in the study. A subset of 73 students completed the survey. A sample of 45 students who completed the survey attended at least one workshop; 35 students participated in the data collection efforts. Twenty-nine students completed three or more workshops. Almost all the students who participated in the data collection efforts were between the ages of 18 and 19. Nearly half of the participants (15 out of the 35) who participated in the data collection efforts were female (~43%). Students identified themselves as White (21), Asian (9), Hispanic or Latino (9), and African American (1); five students identified themselves with multiple racial or ethnic identities. The full demographic information can be seen in Table 3.

4.6 | Data collection

Qualitative data were collected from a total of 35 students who participated in the program using a post-survey distributed immediately after the final workshop (n = 32), a three-month delayed follow-up survey (n = 24), and semistructured interviews (n = 18). All of the students were invited to participate in the post-survey and delayed post-
survey. Only students who had participated in three-plus workshops were invited to participate in interviews. A total of 21 interviews were completed with 18 students. Twelve of these interviews were completed within the subsequent 2 weeks after the last workshop; nine of the interviews were conducted 3 months after the last workshop. This approach was used to explore the longer-term effects of the program and ensure theoretical saturation.

Student participation in the data collection efforts varied leading to considerable variation in the depth of qualitative data collected per student. No incentives were provided to students for their participation in the program or data collection efforts, which may explain the variation in student participation. Table 4 provides an overview of the overall student participation and the level of participation in the different data collection efforts. Appendix B provides a list of pseudonyms with associated workshop and data collection participation information. All data collection efforts were Institutional Review Board approved.

The post-surveys included four open-ended response questions. The primary objectives were to learn about (1) students’ overall impression of the program, (2) how and to what extent students practiced mindfulness, (3) any effects students noticed as a result of the training, and (4) what students learned, that is, main takeaways. The open-ended questions embedded in the delayed post-survey asked students to describe whether they thought they have experienced any changes since the beginning of the program on the following competencies: resilience, empathy, mindfulness, and generic skills (e.g., teamwork, leadership, and self-management). The open-ended questions for the post-survey and

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**Table 3**

| Characteristic       | Number of students |
|----------------------|--------------------|
| Age                  |                    |
| 18–19                | 34                 |
| 20+                  | 1                  |
| Gender               |                    |
| Female               | 15                 |
| Male                 | 20                 |
| Racial identification|                    |
| White                | 21                 |
| Asian                | 9                  |
| Hispanic or Latino   | 9                  |
| African American     | 1                  |

**Table 4**

| Level of participation                  | Number of students |
|-----------------------------------------|--------------------|
| Pre-survey participation                |                    |
| Opened registration link                 | 148                |
| Completed pre-survey                     | 73 of 148 (49%)    |
| Workshop participation                   |                    |
| Attended 1+ workshop                     | 45                 |
| Attended 2+ workshops                    | 35 of 45 (78%)     |
| Attended 3+ workshops                    | 30 of 45 (67%)     |
| Attended 4 workshops                     | 18 of 45 (40%)     |
| Data collection participation            |                    |
| Completed pre–post survey                | 32                 |
| Completed delayed follow-up survey       | 24                 |
| Participated in interview                | 18\(^a\)           |
| Total                                   | 35                 |

\(^a\)There were 21 interviews across 18 students.
delayed post-survey are shared in Appendix C. All students were strongly encouraged to provide candid, objective feedback (good or bad) at the end of the last workshop to minimize bias in the data collection.

The post-program and delayed interviews protocols are presented in Appendix D. The delayed interview protocol was almost identical to the post-program interview, but several questions were rephrased to reflect that the data were being collected 3 months later. All interviews ranged from 10 to 30 min ($M \sim 18$ min). All of the interviews were audio-recorded and transcribed. The interview protocol objectives were the same as the post-survey. The interviews started by reminding the students of the importance of being honest and candid. The interviews were semistructured, allowing the researcher to ask follow-up questions throughout to elicit rich, nuanced information. The interviewer proceeded with the next question once the previous question was sufficiently covered.

4.7 | Data analysis

The interviews were transcribed through Rev’s transcription service. A thematic analysis was conducted solely by the primary author to identify patterns within the data. Emergent codes were discussed and reviewed by the remaining authors throughout the entire coding process, but did not warrant testing of inter-rater reliability. The process followed the best practices for conducting a thorough thematic analysis recommended by Braun and Clarke (2006) and Creswell (2015). The thematic analysis began after gathering the first round of written and interview qualitative data collected immediately after the workshops. Transcripts were read multiple times to become familiar with the data. Open coding of all student excerpts with post-it notes was then performed within three main categories: (1) effects/learning outcomes, (2) mindfulness practice, and (3) general workshop experience. These categories aligned closely with the stated objectives of the data collection (Note: effects and learning outcomes were combined due to considerable overlap.). Axial-coding was also applied in the early stages; written memos were used to help the researcher track relationships between certain codes. The first iteration of the codebook contained 19 distinguishable codes for effects/learning outcomes, 2 broad codes for mindfulness practice, and 5 codes for general workshop experience. Considerable variance in students’ mindfulness practice led to the creation of a continuum rather than distinguishable codes. All of the excerpts were coded using the initial codebook to begin preliminary organization of the data.

The second stage of data analysis was completed after the completion of the delayed data collection. The new transcripts were again read multiple times to become familiar with the data. No new open codes emerged during coding of the second stage data, which indicated that theoretical saturation had been reached during the first stage. A second round of axial-coding was conducted using several strategies to minimize redundancies and overlap of the codes (Saldaña, 2015). The original 19 effects/learning outcomes codes were merged into three themes and seven subcodes. Commonality of codes and variance across students was revealed by re-coding all of the data and quantifying the different effects across each of the 35 participants. The visualization for this can be seen in the table in Appendix B; pseudonyms are used for all of the students to maintain anonymity. For brevity, the emergent themes of mindfulness practice and general workshop experience are not included in the results but are examined in Section 6.

4.8 | Limitations

The primary limitations for this study stem from the small, self-selecting sample of students; variance in participation and data collection across each student; and potential biases introduced in data collection. Since this program was positioned as an extracurricular opportunity, only a limited number of self-selecting students participated. These were students who had an implicit interest in improving their leadership skills and were perhaps more open to mindfulness training than the most engineering students. It is possible that these students thought they had more room for improvement, which could have impacted the results. A placebo effect may also have been created in that the workshop was advertised as a way to improve one’s intrapersonal and interpersonal competencies. The program was not specifically labeled as mindfulness training. The ambiguous program description may have also had a negative effect on recruitment and retention rates and is not necessarily recommended. To support the validity of the findings, it was more important not to allow preconceived notions toward mindfulness to influence who voluntarily participated in this study. Recruiting students who already had an interest in or a favorable opinion of mindfulness would have made the results less generalizable or representative of a general engineering student population.
Another limitation of this study is that there was considerable variance in the level of participation and the data collected for each student. This begins with the initial survey potentially being a barrier to participation based on the difference between those who opened the link and those who completed the survey. A sample of 18 students completed all four workshops and 30 students completed three of the four workshops. Only 18 of the 35 students elected to participate in the interviews. The 17 students included in the data who did not participate in interviews only provided qualitative data from open-ended responses. Interviewing these students may have elicited additional insights into the impacts they experienced. The summarized number of students experiencing various effects (as seen in Table 5) submitted by participants likely does not provide a complete picture of the changes for all students who were involved. It captures improvements that were reported verbally and/or in written form and does not distinguish between minor and major changes. It also does not necessarily signify a student did not experience an effect as the effect just may not have been reported due to the variation in participation. This approach was satisfactory for the exploratory nature of this study, which aimed to include any and all data captured by students regardless of their level of involvement in the program or research. The quantification of the main effects distinguishes which effects were most frequently discussed by the students and, therefore, provides a sense of which effects were most significant or meaningful to the students.

There are also no inferences that can be drawn from the 10 students who attended only one workshop because no data were collected from these students. Five of these students did respond to a follow-up survey question that asked why they dropped from the program. Four students mentioned time conflicts with other activities or work. The fifth student mentioned not having time because of their current workload. It is unclear why the other students dropped and generally whether these students would have experienced similar effects as the students who attended more workshops and participated in the data collection efforts. It is also possible some of these students chose to prioritize other activities, because they did not share the same degree of interest or enthusiasm in mindfulness as the students who attended more workshops.

The workshop facilitator serving as the primary researcher is another limitation associated with this study. This dual role required that he collect survey data, conduct interviews, analyze data, and serve as the primary point of contact for students. The facilitator attempted to mitigate this limitation with students by actively encouraging them to provide their honest feedback. It is possible some students still may have felt uncomfortable disclosing critical feedback. Data analysis may also have been impacted by this dual role as the first author also served as the lone coder of qualitative data. This was done in part because the study was embedded within the first author’s dissertation and he alone had the knowledge to fully grasp the emergent data.

Finally, this study does not provide insight into what extent these types of trainings are scalable within engineering education. The facilitator and primary developer of these workshops had a strong foundation of mindfulness training and extensive practice integrating these concepts into everyday life. It is unclear what level of knowledge and training would be needed to properly facilitate these mindfulness trainings to elicit similar results. This researcher also has a bias toward favoring mindfulness based on his own experiences. It is unclear to what extent this enthusiasm influenced students and may have impacted the findings.

| Effect                           | Number of students |
|---------------------------------|-------------------|
| Mindfulness                     | 29                |
| Intrapersonal competencies      |                   |
| Self-awareness                  | 15                |
| Manage stress/resilience        | 27                |
| Well-being                      | 17                |
| Self-regulated learning         | 17                |
| Interpersonal competencies      |                   |
| Empathy                         | 19                |
| Communication/listening         | 20                |
| Leadership/teamwork             | 18                |

TABLE 5 Number of students experiencing the main effects
RESULTS

The overall data provided were sufficient to reach theoretical saturation and quantify the commonality of the effects with some limitations. It is important to note that only the transfer of the effects and main takeaways by the students to engineering education contexts was explicitly investigated in the interviews. The primary effects or skills were categorized into mindfulness, intrapersonal competencies, and interpersonal competencies. Table 5 summarizes the number of students who experienced the main effects as observed in the qualitative data. See Appendix E for a more detailed breakdown of the effects experienced across each student.

5.1 Theme 1: Improvements in mindfulness

There was evidence in the qualitative data indicating 29 of the 35 students exhibited improvements in their level of trait mindfulness. For a student to be classified as exhibiting a change in mindfulness, they needed to describe a change in their awareness/attention, being more present-oriented, and/or noticing a change in how they perceive their thoughts and/or emotions, that is, attitudes such as acceptance or non-judgment. Collectively, students touched on all of these facets of mindfulness. A general comment is provided by Amy regarding enhanced ability to regulate her attention/awareness. She wrote, “I pay closer attention to the things happening around me and I am more in tune with my thoughts.” A nuanced examination of many of the mindfulness-related quotes revealed students developed an enhanced ability to orient their attention both internally and externally. The students who improved their ability to direct their attention internally were able to develop more self-awareness of their everyday thoughts, feelings, and body sensations within different situations. Fifteen students had quotes that were classified as experiencing an improvement in self-awareness. Robert simply stated this by writing, “I am more aware of what my thoughts are, and I listen to what I am thinking.”

Other students described that they noticed an improvement in their ability to orient or focus their attention externally, including becoming more aware of their environment or surroundings. For example, Carla wrote, “I’ve noticed that I’ve become more oriented with the world around me and that I was able to control myself better in times of stress.” Directing one’s attention externally allowed students to focus their attention more on others. There was also evidence indicating that a student who experienced an increase in self-awareness did not come at the expense of focusing on others. Many students developed both self-awareness and awareness of others jointly. For example, Jose wrote, “This program helped me learn and be more aware of myself and others.” The increased awareness of others is elaborated in the third theme, interpersonal competencies. Many students also began to pay attention and remain present during routine activities they perform regularly including walking, eating, driving, and biking. In general, an enhanced ability to regulate one’s attention was associated with improved focus as highlighted by Shannon who said, “I thought it was super helpful for me in terms of focus. The meditations really helped me realize what I needed to do to get my mind to focus.” To summarize, many students did observe changes in their ability to focus their attention, which is a key facet of mindfulness.

A significant number of students describe being more present-oriented in their daily experiences, which is another key facet of mindfulness. Several students described how they feel like they “live in the moment” more or “focus more on what is happening now.” For example, David wrote, “Slowing down, taking deep breaths, realizing what’s going on, setting goals was really nice to focus on in myself and realize my current situation.” Several students also discussed how they feel like life had “slowed down” for them and that they “take life as it comes” or “moment-by-moment.” An exemplar of this phenomenon is provided by Arthur who said, “It also seems that my life has slowed down, and I can think better about what I am doing in my everyday life, instead of being swept away by the flow of life.” Several students also indicated they are more reflective in certain situations and take time to “pause” every so often and evaluate their situation instead of immediately reacting. Several students described that they notice more often when they are on “autopilot” mode or are “less reactive.” Rodrigo conveyed this idea when he said, “Meditation and mindfulness are really training our brains to act the way we’d like it to instead of reacting to what’s around us.”

A number of students also noted changes in attitudes associated with mindfulness. Most prominently featured was acceptance or students describing how they are more “accepting of challenges.” Several students also described that they are less judgmental of others and are more likely to give others the benefit of the doubt. A notable example comes from Sarah who said, “I used to completely overthink things just sit their wondering if I am going to fail until I fail. I realized that if I just breathe and accept the reality, it’s fine.” These results indicate that students were able to
reperceive situations (as outlined in the theoretical framework section) and not automatically react, leading to enhanced self-regulation.

### 5.2 Theme 2: Improvements in intrapersonal competencies

Improvements in intrapersonal competencies were reported by 33 of the 35 participants. The 29 students who described an improvement in mindfulness also experienced an improvement in at least one intrapersonal competency. The intrapersonal skills developed by the students were grouped into four main categories: (1) enhanced ability to manage or bounce back from stress, that is, resilience, (2) improvement in well-being, (3) greater focus on personal development, and (4) improved ability to focus on school-related tasks and/or greater productivity. These collective findings suggest the mechanism of reperceiving led to the other mechanisms of mindfulness. For example, enhanced self-regulation, including the ability to mediate stress responses, leads to an increased capacity to recover from stressors, which allowed for greater achievement of well-being. This improvement in functioning transferred to improvements in self-regulated learning leading to greater focus on school-related tasks and increases in productivity.

A subset of 27 students described an enhanced ability to self-regulate their thoughts/emotions, stress, and/or anxiety. These students saw a reduction in (or relief of) stress, anxiety, or feeling overwhelmed, and rumination. A noteworthy comment came from Jose who shared:

> A BIG effect it had was decreasing the frequency and severity of my anxiety. Coming to this program, one of my goals was not to improve or get help with my anxiety but it made a big difference. Since I have been practicing mediation every morning, I have noticed that I am less anxious and don’t have as many anxiety attacks, which helps me enjoy my time and days more.

The students largely attribute these improvements to changes in their mindfulness. David for example mentioned, “I’ve also felt more calm in stressful situations actually, without overreacting or overthinking. I do not exactly know what is helping me do that, but I figured it’s a part of practicing mindfulness that has helped me center in more at times I need to.” Becoming more aware of and managing everyday thoughts, emotions, and stressors have greatly alleviated much of the stress or anxiety students had and has led to improvements in resilience, or the ability to bounce back from stress. In another example, Rodigro stated, “I feel like my tolerance is slowly getting better toward stress.” Carla concisely wrote, “I think I’ve grown in my ability to overcome obstacles and hardships.” Courtney elaborated on the idea that she is less negatively affected by stress by saying, “I still get stressed and everything from school and whenever life. But I feel like it does not affect me as much. I know it’s there, but in my mind, I know it’s okay. It’s just what it is and I can get through it.” A number of students described being able to more readily recognize stress, being able to tolerate or accept it, and being able to identify ways to overcome it. This is also represented well by the following quote from Samantha who said, “I think I have grown better self-awareness for recognizing when I am stressed and evaluating what I need to do to overcome that stress and take care of myself.” These examples illustrate that stressful thoughts and emotions have not necessarily disappeared but that students’ perception of them has changed. Students appear to be able to more effectively tolerate or “expose” themselves to these stressors and actually reperceive the situation. As outlined in the theoretical framework section, through increased exposure and reperceiving, students appear to be able to better recognize when they are ruminating and can better control how they react, leading to significant improvements in their resilience.

Naturally, an improved ability to self-regulate one’s thoughts and emotions leads to improvements in well-being. Approximately half (17 of the 35 students) of the students explicitly mention that their life has improved in some capacity since the culmination of the program due to improvements in intrapersonal competencies. Common adjectives used among the students included feeling more at peace, content, calm, at ease, and/or clear-minded. For example, James wrote, “I have noticed that I seem more mindful in general, I appreciate little things in life more often. I also feel a lot less stressed and more relaxed.” Others described feeling more confident, curious, optimistic, and energetic as demonstrated by Mary who wrote, “I have noticed a strong increase in interest and optimism in my life.” Some students generally noted that they feel like life is more enjoyable. A few students mentioned that they are more appreciative of positive things in their life and less focused on negative occurrences. For example, Rodrigo divulged, “The more you do practice mindfulness, you start picking out the more positive things that happen during your day unconsciously. Your negative thoughts start to drain out of your mind.” Arthur also noticed that being more mindful or self-aware of his
thoughts helped him identify negative thought-patterns. He commented, “It's kind of made me a more positive person and I identify negative in my own thinking and in others thinking, and I try to do my best to reduce it because nobody wants negativity.” The 17 students who explicitly mentioned a positive life outcome were also classified as experiencing improvements in well-being. These improvements often went hand-in-hand with improvements in self-regulation and/or mindfulness. This is exemplified perfectly by Courtney who became considerably more aware of her rumination and now is able to manage her thoughts more effectively:

I felt that I was more present in my actions and was also more aware of my surroundings. When I felt stressed throughout the week, I found that it was easier to calm myself down and put everything into a better perspective. Overall, I feel that the program has heightened my general mood and has given me a sense of peace. It amazes me how much I would (and still do at times) get wrapped up in my thoughts and let them cycle around in my head throughout the day. Now that I am more aware of this, I feel as though I have more control over my thoughts and do not let them consume me quite as much.

Improvements in self-regulation also transferred to improvements in how students self-regulated their learning. Overall, 17 of 35 students described changes related to an enhanced ability to focus on school-related tasks, manage their goals and tasks more effectively, and develop a growth mindset toward school. Several students described feeling less overwhelmed by their workload and more readily able to focus on school-related tasks, leading to improvements in productivity. A salient example that highlights an increased resilience toward school-related work comes from Jose who articulated a shift in perspective in how he approaches his assignments:

Let's say I get assigned a bunch of assignments. That's what usually would start some stress or feed into my anxiety. I am able to calm myself down in a way and tell myself it's not that bad. It's just assignments—take it step-by-step. You can only do one thing at a time. I've had anxiety for a long time. It's hard to explain that it is helping my day overall. Things that would usually stress me out don't affect me as much.

Multiple students also shared they were “more focused in class” and “could focus more on their homework.” Harry for example wrote, “I listen more and intake more information the more that I focus on stopping and breathing instead of just trying to focus more on the instructor.” In another example, Ravi wrote, “Meditation really helped me center my mind in a task. My mind tends to wander a lot and it really helped me focus. I did try it on my own time and it increased my productivity.”

Students were also able to more effectively self-regulate their learning by improving on their ability to develop goals, prioritize tasks, and actively manage and organize their schedule. Several students shared that they are more scheduled, structured, and/or organized now, especially in relation to prioritizing important personal and school-related work and goals. For example, David wrote, “I have noticed that I have been able to organize my schedule a little bit more effectively, prioritizing.” Gabriel succinctly stated, “After the program, I found that I'm able to focus on my goals and whatever would benefit me as a person.” Meanwhile, Carla felt like she was more prepared and focused each day: “I was more prepared schedule-wise. I was able to remember when I had a meeting or class whereas before I struggled to remember what classes I had each day. I felt more focused in what I was doing each day.” Other students developed a habit of tracking the tasks they need to complete such as Jose who shared, “I now keep a to-do list on my phone with all of the due dates and today what I am going to do.” This increased organization has consequently led to students being less prone to procrastination. For example, Tanya alleged, “The program motivated me to procrastinate less to make things easier.” George affirmed this statement by stating, “The course encouraged me to take incremental steps in accomplishing my goals and tasks, especially homework, rather than become a procrastinator.” These findings provide evidence of the mechanism of values and goals clarification as students appear to be more goal-oriented and are more effectively prioritizing what is important to them.

Developing a stronger goal-orientation also applied to students' personal goals as well as self-improvement. A few students shared that they are intentional about making time for their personal hobbies and taking care of themselves. Several students also shared that they now allocate more time to reflect on ways to improve themselves. A strong example of this comes from Mary who shared how she has integrated reflection as a daily habit: “I have also done a form of debrief at the end of each day by reflecting on what stressed me out or upset me, how to fix this, and the things I think I did well and could improve on.” Tanya mentioned that she already had a habit of reflecting on self-improvement but does it “in a more productive and positive way now.”
Another connection to self-regulated learning that emerged is that a number of students began to develop a positive outlook toward school. Mary specifically noticed adopting a growth mindset toward her chemistry class, while Jose remarked, “I learned some skills to deal with school and life as it comes at me and to have a positive outlook on stuff and think of them as learning experiences.”

5.3 Theme 3: Improvements in interpersonal competencies

Mindfulness has a strong connection with interpersonal competencies, which was supported by the findings from this study. A total of 25 students described an improvement in their interpersonal competencies. These changes were organized into three main categories: empathy, communication, and leadership/teamwork. Nineteen students discussed empathy as one of the main skills they learned from the program. Collectively, the students described both the cognitive and affective dimensions of empathy and an increased desire to understand the perspective of others. A powerful example of this comes from Rodrigo who described cultivating empathy from the program:

I feel like I have more empathy for people. Feeling what they are feeling more. And then you realize what they are going through as well and you start seeing everything from a different perspective. For example, before the program, I would judge people a lot but now after this program, I try to see things from their perspective more.

Many of the students who noted a change in empathy have observed the benefits from practicing empathy more, including understanding others more, being less judgmental, and generally having more positive interactions. These findings suggest that students clarified empathy as a value. Yasmael noted that “empathy is the most major thing I feel I will take away” and that his “conversations with others are more elaborative.” Students like Yasmael credit mindfulness in supporting their ability to practice empathy as they are “not really in a rush anymore” and are less reactive or judgmental toward others. For example, Mary shared:

When I’m interacting with other people too, I really try and understand their side and I think that’s helped me give people the benefit of the doubt a lot more. This has therefore increased my intrapersonal skills, because I am not as quick to come to conclusions about others, my own feelings, and other people’s feelings/actions. I think this has increased my awareness of how to display good intentions and genuinely.

Twenty students also described improvements in their communication skills. One common theme was students feeling more open and confident. This has led to different benefits such as making it easier to connect with others, being more relatable, and being able to share ideas more effectively. For example, Carla shared that she “feels more open to making friends and making connections” and that “the program showed me I can be more open to other people.” Maria described herself as introverted and wrote, “I communicate more with others without making it too uncomfortable for myself.” Jose said that he is now “more comfortable presenting [his] ideas.” These findings are particularly noteworthy as engineering programs have largely struggled in improving the oral communication skills of students (e.g., Meier et al., 2000; Nair et al., 2009). These findings indicate mindfulness training can support greater openness and an ability to convey ideas more effectively.

Students have been able to apply mindfulness to orient their attention more toward others and listen more effectively. Stephen for example shared, “I think that I also pay attention more to what people are saying in a conversation,” while Jane wrote, “I did try to be more mindful and listen to conversations more attentively.” A number of students noticed becoming more aware of internal distractions that previously hindered their listening skills such as thinking about what they were going to say next instead of actually listening. Courtney described this phenomenon well: “I feel like I’ve always listened to people, but now I feel like I’m more focused on listening to what they have to say versus how I’m going to respond.” This finding suggests that students can self-regulate distracting thoughts and can reorient their attention to others when appropriate. Active listening has helped improve some student’s ability to understand the perspective of others. David for example noted that “[active listening] helps me understand people’s statements.” Wade shared, “Through listening to what others were talking about and focusing on what they were saying in my head, I was able to understand them more emotionally.” These findings illustrate that mindfulness can augment
listening skills. An important skill engineers need to understand the needs of various stakeholders in their work (Lappalainen, 2009; Passow & Passow, 2017).

Eighteen students discussed improvements in their teamwork and/or leadership skills. Many of these students noticed how empathy and active listening have enhanced their teamwork skills. These students described being less controlling, more open to new ideas, having a greater desire to seek the input of their team members and ensuring the perspectives of others are heard. These students shared that this has enhanced their group experiences, supported conflict-resolution, and overall led to improvements in productivity and outcomes. A good example of this comes from Shannon who acknowledged that “the importance of empathy in engineering stuck with [her]” and how she was able to transfer the ideas of empathy to an engineering group project. She observes and remarks, “It’s allowed me to listen to the team better instead of taking control, which is what I used to do. It’s made it easier because I am not trying to do everything myself.” Jared described empathy also as a major takeaway and as a way “to make teamwork more efficient.” He elaborated on this by explaining that “It’s related to conflict-resolution. It can help you detect when a teammate feels like their voice is not being heard and ask them ‘well what do you think about this?’.” These findings provide evidence that mindfulness can support engineering students in more skillfully working with others in project-based learning classes and leverage these types of experiences more effectively to develop their teamwork skills.

Many students also observed how empathy and active listening have enhanced their leadership skills. Several of the more introverted students noticed that they now feel more confident in their ability to step up in a leadership role as a result of integrating empathy and active listening skills in their group work. Two particularly notable examples of this are shared by two students. In an interview, Carla articulated her maturation as a leader:

I feel like I have been listening more to others instead of focusing on making a remark to what they said. Or saying “me too.” It’s more focusing on what they mean and supporting them instead of bringing myself into it. I would relay the messages between everyone, which was really interesting because I usually don’t take a leadership role within my groups. There were some points where I was the only one available but other times it felt like I was stepping up to bring all of the ideas together, or bring back up points that others left behind. I felt very comfortable with taking the leadership role over time. At first it felt really weird but over time I felt more comfortable with it and felt prepared to take on a leadership role.

Carla described becoming more comfortable being a leader and an ability to seek out and integrate the ideas of the other team members. This is a striking example demonstrating that leaders are made, not born. It illustrates that mindfulness can support the development of interpersonal competencies to the point where students, who do not self-identify as leaders, feel more confident in their ability to step into this role. In another noteworthy example, Gabriel described that before the program he had difficulties working with others and was “hesitant to provide input on certain things.” Since the culmination of the program, Gabriel perceived a significant improvement as he said:

I’ve learned to break out of my shell one step at a time and take a leadership role every now and then. I used to be more behind the scenes as far as organization and time management, but I’ve found that I’m slowly becoming more all around. I’ve grown to be more flexible and adapt to change while trying my best to avoid over-analyzing things.

Gabriel’s experience provides another compelling example that mindfulness can help introverted engineering students begin to take more of a leadership role on their teams. These examples illustrate how mindfulness may support some engineering students in “breaking out of their shells” and more readily take advantage of their project-based learning experiences to practice teamwork and leadership skills.

6 | DISCUSSION

The findings from this exploratory study indicate that mindfulness training can support the development of intrapersonal and interpersonal competencies among first-year engineering students. There was evidence of the mindfulness mechanism of reperceiving in that students describe a shift in how they viewed those thoughts and emotions. Reperceiving led to improvements across intrapersonal competencies including self-awareness, self-regulation, resilience, self-regulated learning, and well-being. Students also reported observing notable improvements across interpersonal
competencies including empathy, communication, teamwork, and leadership. A strong majority of the students described experiencing improvements in mindfulness even after only 4 weeks. Some of the students had difficulty fully articulating the changes they experienced, but collectively they did touch on all aspects of the current conceptualizations of mindfulness. The students described an enhanced ability to focus their attention internally and/or externally, a greater sense of being attuned with their everyday thoughts and emotions, more frequently being immersed in moment-to-moment activities, and an increased adoption of attitudes like acceptance, openness, curiosity, and non-judgment.

The findings provide evidence of the mechanisms of mindfulness—reperceiving; exposure; self-regulation; cognitive, emotional, and behavioral flexibility; and values clarification—indicating that the changes in mindfulness led to improvements in intrapersonal and interpersonal competencies. There was evidence indicating many students became more self-aware of their everyday thought-patterns, emotions, and stressors. Students described an improved ability to expose themselves to and tolerate stressors and were less prone to being reactive, allowing for improved cognitive, emotional, and behavioral flexibility. As a result, many students described feeling less stressed or anxious, not being as negatively affected by previous stressors, and experiencing greater well-being (i.e., feeling more peaceful, optimistic, energetic, confident, and clear-minded). There was also evidence that mindfulness could enhance students’ ability to self-regulate their own learning. A number of students described feeling like they could focus better on school-related work and pay attention better in class. A few students noted they had adopted a more positive mindset toward learning, while feeling greater resilience to school-related challenges and an increased goal-orientation. Others described becoming more organized, scheduled, and procrastinated less on completing school-related work. These overall improvements described by students align well with the value clarification mechanism of mindfulness and support the notion that mindfulness training can support learning.

Another major focus of the training was to provide students with guidance on how mindfulness can be used to support the development of interpersonal competencies. The mechanisms of reperceiving; self-regulation; cognitive, emotional, and behavioral flexibility; and values clarification appear to play a role in augmenting empathy, teamwork skills, and leadership skills for engineering students. There was evidence that students clarified empathy as an important value with utility in engineering contexts and, through improved self-regulation of their attention, could act in a manner congruent with this value by improving their active (or mindful) listening skills. Through empathy and active listening, students observed more meaningful interactions and found it easier to connect and build relationships. The cultivation of empathy and enhanced communication skills transferred to improvements in teamwork and leadership skills. Several self-identified introverted students noticed that they are more confident and open in their interactions and expressed a greater willingness to share their perspective, especially in group settings. On the other side of the spectrum, several students described being less controlling, more open to the ideas of others, and more actively seeking and integrating the input of other team members. This has translated to improved group experiences and students feeling more confident in managing conflicts and their leadership skills.

### 6.1 Impressions of workshop and variations in practice

The overall changes varied for each student depending on their previous experiences and knowledge on these topics. For example, several students found the content to be interesting but experienced little to no change because they were already familiar with it. The overwhelming majority of students found value in integrating many of the tools and techniques shared in the mindfulness training within their personal lives. The overall feedback provided indicates the students were receptive to learning about mindfulness and engaging in training through meditations, reflections, and discussions. The workshop was well-received with all 35 students having a positive impression of the it. Only one student described experiencing no tangible benefit from the program. The common adjectives students used to describe the workshop were enjoyable, rewarding, interesting, informative, useful, and engaging.

Several students discussed having different expectations of the programs based on the description on the flyer or acknowledged they were not interested in mindfulness prior to the workshop. Some students thought it was odd initially or even had negative perceptions of meditation going into the first exercise (e.g., “it was a waste of time”). This suggests that the program did draw a more representative sample of students with varying levels of interest in mindfulness. It also suggests that some engineering students may possess negative biases toward mindfulness. The primary researcher expected this, which is why the first workshop includes research evidence of the utility of mindfulness and students were encouraged to keep an open mind. Students also had very different experiences of the meditations. Some
students found the in-class meditations to be challenging and found them easier to do at home, while others found it easier to meditate in class versus on their own. A few students mentioned that they thought the in-workshop meditations were their favorite part.

There was considerable granularity in how and to what extent the students practiced cultivating mindfulness on their own, which likely impacted the influence of the program. For some students, a mindfulness meditation practice resonated with them, and they were able to integrate a formal practice into their daily lives, while for others simply taking time to reflect, pause, or immerse themselves fully in an activity was enough to cultivate mindfulness. Evidence was provided by 12 students who integrated a formal meditation practice. The majority of students appeared not to integrate a formal meditation practice. There was evidence indicating 11 of these students preferred to integrate an informal mindfulness practice or add “mindful moments” into their lives. These mindful moments often took the form of connecting with their physical body in some capacity such as taking deep breaths, focusing on their movement, or concentrating on what they were doing in that moment (e.g., walking, eating, biking, eating, etc.). In general, student’s mindfulness practice varied from a few minutes a week up to 30-min per day. Students, thus, chose to take the concepts of the workshop and apply them in a way that makes sense for them.

### 6.2 | Implications

This study has implications for engineering educators, especially those involved in designing first-year engineering programs. Engineering faculty and administrators should be aware of the major implications intrapersonal and interpersonal competencies can have on students' academic performance and future career success. It is especially important to continue to identify approaches to foster these competencies within the current climate of higher education. The coronavirus pandemic has forced many colleges to convert their classes to hybrid or online modalities. Students, especially first-year students, are not experiencing the same types of opportunities to connect with their peers and it is likely many students are feeling more isolated or lonely than under normal conditions. Emerging research indicates that the current pandemic is exacerbating mental illness (Ornell et al., 2020; Taquet et al., 2020). Mental illness, including high levels of stress and anxiety, has been demonstrated to negatively affect academic performance (American College Health Association, 2018; Storrie et al., 2010; Vitasari et al., 2010). Many of the intrapersonal competencies (e.g., self-regulation) developed and outcomes experienced (e.g., reduced anxiety) from mindfulness would likely support students during this difficult time and could even support retention, which is already notably low in engineering with four-year graduation rates just above 30% as of 2014 (Yoder, 2016).

Even in normal circumstances, the combined benefits in intrapersonal competencies (e.g., self-regulated learning) with the notable improvements in interpersonal skills (e.g., communication, teamwork, and leadership) suggest mindfulness can be a powerful support mechanism for how students experience and manage their engineering courses. In particular, first-year engineering design classes are becoming the norm across institutions and may offer an ideal context to situate trainings, such as mindfulness, that support intrapersonal and interpersonal competencies. In their sample of 197 engineering departments, Borrego et al. (2010) found that approximately 86% of students are estimated to be participating in design projects in a first-year engineering course. Several powerful student examples from this study (e.g., Carla and Gabriel) illustrate how students may be more equipped through the mindfulness training to leverage these first-year design courses to improve their intrapersonal and interpersonal competencies. The enhanced self-regulation skills students described align closely with the concept of metacognition, which has been described as a driving mechanism in active-learning experiences in engineering education (Vos & de Graaf, 2004). Students’ ability to effectively metacognitively monitor and control their thoughts transferred broadly to learning and, in general, behaving in a manner congruent with their values and goals.

Finally, with improved intrapersonal and interpersonal competencies, students may be more equipped to navigate empathetic and human-centered design approaches. Several researchers have highlighted the value of empathy in engineering (e.g., Walther, Miller, & Sochacka, 2017), particularly in engineering design when understanding and engaging stakeholders and users (Leonard & Rayport, 1997; Hey et al., 2007) or during idea generation (Gray et al., 2015). The findings from this study largely mirror the findings of Spanjian (2019), who evaluated the impact of mindfulness training on 10 practicing engineers. The findings from this study lend credence to the idea that integrating mini-interventions intended to develop intrapersonal and interpersonal competencies—such as mindfulness—into engineering design courses would likely enhance engineering students’ experience and more adequately prepare them with the skills they will need to be successful in an increasingly collaborative, integrated workforce (Lappalainen, 2009).
Faculty and administrators are encouraged to review the findings and be aware of the value of promoting intrapersonal and interpersonal competencies such as self-regulation and empathy. Engineering faculty and administrators should be conscientious in how they are modeling these skills to students and conveying their utility. It is a shared responsibility among engineering educators to prepare engineering students with the intrapersonal and interpersonal competencies they will need to be successful in their future careers.

6.3 | Future work

Future work needs to involve design and development research to explore the feasibility of integrating mindfulness training within engineering education. First-year engineering design and/or academic success courses and programs would likely be a good, natural fit for mindfulness content. Future research could evaluate different approaches to integrating mindfulness into these first-year courses and explore the utility and outcomes of these interventions. For example, if mindfulness is integrated in a first-year design course, research could investigate how these interventions impact students’ experience/mindset/performance and overall class/team dynamics as well as how students navigate the design process. It is likely some sort of module or introductory lecture would be required to introduce mindfulness to students, one that provides information on mindfulness theory, research, and its utility within an engineering context. Brief (5 min or less) mindfulness meditations can then be integrated during subsequent classes. To do live trainings and meditations, qualified mindfulness facilitators would likely need to be identified. Engineering schools could partner with internal or external organizations that can provide such qualified facilitators. Another option would be to use a Train the Trainer approach and train academic advisors or interested instructors to facilitate the workshops. Both of these options would likely be logistically challenging and require extensive administration work. An alternative would be to provide online content in the form of videos and modules. There are now myriads of free mindfulness meditation videos and audio recordings available including apps such as Headspace or Calm. There are also numerous seminars and talks on mindfulness that describe the theory and research. These videos or audio recordings could be played during class or assigned as homework, with students being required to log their meditations and submit short, written reflections. It is unclear how an online or blended approach would affect student outcomes. Introductory engineering or university 101 academic courses could be leveraged to facilitate in-person discussions and activities for students to fully grasp the applicability of mindfulness training in engineering education and personal life contexts. Finally, another option is to simply maintain the status quo of having mindfulness be offered as an extracurricular program that students elect to participate in. This would allow student affairs or another institutional organization to manage such trainings; however, these programs would likely not be tailored for engineering students, and it is unclear how many engineering students would actively seek out these types of opportunities.

7 | CONCLUSION

There has been little work connecting mindfulness research to engineering education. This exploratory study of a mindfulness training program was designed, developed, and implemented for engineering students. The findings provide evidence that mindfulness can indeed support the development of intrapersonal and interpersonal competencies that transfer directly into supporting students’ engineering education experience as well as their personal lives. The outcomes strongly align with the mechanisms of mindfulness shared in the theoretical frameworks section leading to notable improvements in self-regulation skills, well-being, empathy, teamwork, and leadership. Improvements in mindfulness enabled students to be more present and aware in their daily interactions, which improved their ability to connect with and understand the needs of others. Future work will need to be conducted to evaluate the feasibility of scaling or integrating the content in this program within an engineering school.

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APPENDIX A

Flyer and workshop description

Note: Details on registration and location have been blacked.
# APPENDIX B

## Student participation information

| Name       | Gender | Age | Major                              | Days attended | Data collection participation | Pre–post survey | Longitudinal survey | Interview |
|------------|--------|-----|------------------------------------|---------------|-------------------------------|----------------|---------------------|-----------|
| Charles    | M      | 18  | Mechanical Engineering             | 4             |                               | 1              | 1                   | 1         |
| Amy        | F      | 18  | Mechanical Engineering             | 4             |                               | 1              | 1                   | 1         |
| Stephen    | M      | 18  | Civil Engineering                  | 4             |                               | 1              |                     |           |
| Ysmael     | M      | 18  | Robotic Engineering                | 4             |                               | 1              | 1                   | 1         |
| Carla      | F      | 18  | General Engineering                | 4             |                               | 1              | 1                   | 1         |
| Rodrigo    | M      | 19  | Automotive Systems Engineering     | 4             |                               | 1              |                     |           |
| Sarah      | F      | 18  | Computer Science                   | 4             |                               | 1              | 1                   | 1         |
| Tanya      | F      | 18  | Mechanical Engineering             | 4             |                               | 1              |                     |           |
| Eve        | F      | 19  | Biomedical Engineering             | 4             |                               | 1              |                     |           |
| Greg       | M      | 18  | Software Engineering               | 4             |                               | 1              |                     |           |
| Arthur     | M      | 18  | General Engineering                | 4             |                               | 1              | 1                   | 1         |
| Shannon    | F      | 18  | General Engineering                | 4             |                               | 1              | 1                   | 1         |
| Maria      | F      | 18  | Computer Systems Engineering       | 4             |                               | 1              | 1                   | 1         |
| Roy        | M      | 18  | Aerospace Engineering              | 4             |                               | 1              | 1                   | 1         |
| Mary       | F      | 18  | Civil Engineering                  | 4             |                               | 1              |                     |           |
| George     | M      | 18  | Mechanical Engineering             | 4             |                               | 1              |                     |           |
| Courtney   | F      | 18  | Biomedical Engineering             | 4             |                               | 1              | 1                   | 1         |
| Natalie    | F      | 19  | Human Systems Engineering          | 4             |                               | 1              | 1                   | 1         |
| Sharon     | F      | 18  | Chemical Engineering               | 3             |                               | 1              | 1                   | 1         |
| James      | M      | 18  | Aerospace Engineering              | 3             |                               | 1              |                     |           |
| Tanya      | F      | 18  | Mechanical Engineering             | 3             |                               | 1              | 1                   | 1         |
| Jose       | M      | 18  | Mechanical Engineering             | 3             |                               | 1              | 1                   | 1         |
| Naresh     | M      | 18  | Electrical Engineering             | 3             |                               | 1              |                     |           |
| Joseph     | M      | 18  | Computer Systems Engineering       | 3             |                               | 1              |                     |           |
| David      | M      | 18  | Computer Science                   | 3             |                               | 1              |                     |           |
| Asaf       | M      | 18  | Engineering Management             | 3             |                               | 1              |                     |           |
| Ravi       | M      | 19  | Materials Science Engineering      | 3             |                               | 1              |                     |           |
| Jane       | F      | 18  | Computer Systems Engineering       | 3             |                               | 1              | 1                   | 1         |
| Harry      | M      | 27  | Computer Science                   | 3             |                               | 1              |                     |           |
| Joan       | F      | 18  | Computer Science                   | 2             |                               | 1              |                     |           |
| Wade       | M      | 18  | Computer Science                   | 2             |                               | 1              |                     |           |
| Vishal     | M      | 18  | Automotive Systems Engineering     | 2             |                               | 1              |                     |           |
| Robert     | M      | 18  | Industrial Engineering             | 2             |                               | 1              |                     |           |
| Samantha   | F      | 18  | General Engineering                | 2             |                               | 1              |                     |           |
| Gabriel    | M      | 18  | Computer Science                   | 1             |                               | 1              |                     |           |

|                    |        | 32  | 24 | 18 |
APPENDIX C

Survey opened-ended questions

Post-survey open-ended questions
1. What were your overall impressions of the program? What did you like about the program? What did not you like?
2. Did you practice mindfulness on your own either formally (e.g., meditation) and/or informally (e.g., take a deep breath, mindful moment)? Please be as specific as possible on what you tried!
3. What effects, if any, have you noticed since the beginning of the mindfulness program?
4. Overall, what are some of the major things you will take away from your participation in the program (e.g., insights, new habits, etc.)?

Longitudinal-survey open-ended questions
1. The collection of items above describes resilience. How would you describe your level of resilience now in comparison to before the Inner Engineering Program?
2. The collection of items above describes mindfulness. How would you describe your level of mindfulness now in comparison to before the Inner Engineering Program?
3. The collection of items above describes empathy. How would you describe your level of empathy now in comparison to before the Inner Engineering Program?
4. The collection of items above describes interpersonal, teamwork, leadership, critical-thinking, and self-management skills. How would you describe your skill level in these areas now in comparison to before the Inner Engineering Program?

APPENDIX D

Interview protocols

Post-program interview
1. What were your overall impressions of the program?
   a. What did you like about the program?
   b. What did not you like?
2. Did you practice mindfulness on your own both formally and informally?
   a. If yes, what did you do and to what extent did you practice?
3. Overall, what are some of the major things you will take away from your participation in the mindfulness program?
   a. Can you tell me about any insights you experienced during the mindfulness program?
4. What effects, if any, have you noticed since the beginning of the mindfulness program?
   a. How has this effect you have experienced supported you (if at all)? How about in school?
   b. Have you noticed any changes in your interactions with others? How about in an academic setting (e.g., group projects)?
   c. A core focus of this program was mindfulness. Do you feel like this changed? If so, how do you think practicing mindfulness has supported you?
   d. A core focus of this program was developing empathy through mindfulness. Do you feel like this changed? If so, how do you think practicing empathy has supported you?
   e. Has the mindfulness program influenced your engineering education experience in any way? If so, please elaborate how and in what contexts

Delayed interview protocol
1. What were your overall impressions of the program?
   a. What did you like about the program?
   b. What did not you like?
2. Have you maintained any sort of mindfulness practice since the program ended?
   a. If yes, what did you do and to what extent did you practice?
3. Overall, what are some of the major things you will take away from your participation in the mindfulness program?
   a. Can you tell me about any insights you experienced during the mindfulness program?
4. What effects, if any, have you noticed since the beginning of the mindfulness program?
   a. How has this effect you have experienced supported you (if at all)? How about in school?
   b. Have you noticed any changes in your interactions with others? How about in an academic setting (e.g., group projects)?
   c. A core focus of this program was developing empathy through mindfulness. Do you feel like this changed? If so, how do you think practicing mindfulness has supported you?
   d. A core focus of this program was empathy. Do you feel like this changed? If so, how do you think practicing empathy has supported you?
   e. Has the mindfulness program influenced your engineering education experience in any way? If so, please elaborate how and in what contexts
APPENDIX E

Individual student effects experienced from program

|                                      | Intrapersonal competencies | Interpersonal competencies |
|--------------------------------------|----------------------------|----------------------------|
|                                      | Mindfulness | Self-awareness | Manage stress/resilience | Well-being | Focus on personal development | Focus on school work | Total | Empathy | Communication/listening | Leadership/teamwork | Total |
| Charles                             | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Amy                                 | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Stephen                             | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Ysmael                              | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Carla                               | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Rodrigo                             | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Sarah                               | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Tanya                               | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Eve                                 | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Greg                                | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Arthur                              | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Shannon                             | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Maria                               | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Roy                                 | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Mary                                | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| George                              | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Courtney                            | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Natalie                             | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Sharon                              | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| James                               | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Tanya                               | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Jose                                | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Naresh                              | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Joseph                              | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| David                               | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |
| Asaf                                | 1           | 1              | 1                         | 1          | 1                             | 1                    | 1     | 1       | 1                        | 1                 | 1     |

(Continues)
|                  | Intrapersonal competencies |                     | Interpersonal competencies |                     |
|------------------|---------------------------|---------------------|---------------------------|---------------------|
|                  | Mindfulness               | Self-awareness      | Manage stress/resilience | Well-being         | Focus on personal development | Focus on school work | Total | Empathy | Communication/listening | Leadership/teamwork | Total |
| Ravi             | 1                         |                     |                           | 1                   | 1                      |                      | 1     | 1       |                     |                    | 1     |
| Jane             | 1                         |                     | 1                         |                     | 1                      |                      | 1     | 1       | 1                   |                    | 1     |
| Harry            | 1                         |                     |                           | 1                   | 1                      |                      | 1     | 1       |                    |                    | 1     |
| Joan             |                           |                     |                           |                     |                        |                      |       |         |                    |                    |       |
| Wade             | 1                         |                     |                           |                     | 1                      |                      | 1     | 1       | 1                   |                    | 1     |
| Vishal           | 1                         |                     |                           | 1                   | 1                      |                      |       |         |                    |                    |       |
| Robert           | 1                         |                     | 1                         |                     | 1                      |                      | 1     | 1       | 1                   |                    | 1     |
| Samantha         | 1                         |                     | 1                         |                     | 1                      |                      | 1     | 1       | 1                   |                    | 1     |
| Gabriel          | 1                         |                     | 1                         |                     | 1                      |                      | 1     | 1       | 1                   |                    | 1     |
|                  | 29                        | 15                  | 27                        | 17                  | 12                     | 10                   | 33    | 19      | 20                  | 18                  | 25    |