



Thriving for Engineering Students and Institutions: Definition, Potential Impact, and Proposed Conceptual Framework

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Thriving for Engineering Students:

Definition and Proposed Conceptual Framework

This research paper summarizes existing research and reports regarding factors that contribute to engineering student success and organizes these factors into a conceptual framework of engineering thriving. Despite the growing recognition of the importance of noncognitive factors in engineering student success and the vast literature on the educational benefits of thriving, a conceptual framework for thriving in the engineering context is currently lacking. In this paper, we propose a theoretical conceptual framework of engineering thriving based on an exploration of a limited set of existing research and professional reports and face validity checks with faculty.

We define engineering thriving as developing and refining competencies that contribute to successful engineering students with optimal functioning. In the pursuit of developing successful engineering students, this proposed framework for engineering thriving brings together and operationalizes academic and personal competencies that support valued outcomes for engineering students. To inform future steps of research into engineering thriving, we cross-compared several competencies with those from existing frameworks of thriving from other fields to identify gaps. Findings from research on engineering thriving are meant to complement, rather than replace, the traditional engineering education in supporting engineering students' success.

Focusing on thriving in the engineering context represents a paradigm shift in engineering education that has great potential to inform new strategies to further improve the way engineering is learned, taught, and practiced. This proposed conceptual framework may serve the engineering education community by providing a first step in understanding and conceptualizing thriving in the engineering context to support more engineering students to thrive through graduation and beyond.

Introduction

Since becoming its own established field, engineering education has primarily been preoccupied with the problems, weaknesses, and struggles of educating undergraduate engineering students (Lohmann & Froyd, 2010). Historically, engineering literature and professional reports heavily emphasize achievement-related outcomes. These reports particularly emphasize the need to address engineering students' problems, weakness, and struggles that impede their achievement on cognitive measures. By prioritizing academic achievement as the primary success metric for undergraduate engineering students, we have made great strides in better understanding and

addressing the academic barriers to success in engineering, especially in retaining the students at risk of leaving the major.

While addressing the problems, weaknesses, and struggles to engineering student achievement is important, we argue that fixing these problems, weaknesses, and struggles does not, in and of itself, result in building solutions, strengths, and accomplishments valued in engineering. In other words, fostering successful engineering students requires more than just resolving their problems, weaknesses, and struggles related to academic achievement. Seligman, considered one of the founding fathers of Positive Psychology, has found that the skills to build personal strengths differ from those that mitigate weaknesses (Seligman, 2013). Under this premise, interventions that buffer against student failure differ from those that support students to build the range of cognitive and personal outcomes valued in engineering.

With the goal of broadening success metrics for undergraduate engineering students beyond just academic competencies, we define and operationalize "engineering thriving" as a series of competencies relevant to engineering student success and optimal functioning. We operationalize engineering thriving through a novel conceptual framework that includes more positive interpersonal (such as belongingness) and intrapersonal (such as mindfulness) competencies that complement the field's traditional focus on academic competencies (such as GPA). This approach to conceptualizing thriving is consistent with Seligman's (2013) claim that interventions which mitigate problems differ from those that foster thriving.

The purpose of this conceptual framework for engineering thriving is to take the first step in defining the competencies relevant to engineering student success, as informed by a search of engineering education literature, review of professional reports relevant to undergraduate engineering student success, feedback from engineering education faculty and conversations with undergraduate engineering students. As a result, all competencies that comprise this conceptual framework of engineering thriving were derived from existing narratives in engineering. Overall, this paper addresses the growing need for a clear definition of engineering thriving relevant to undergraduate engineering students.

While few would challenge the pursuit of thriving as a pertinent educational goal, discussions of thriving remain largely missing in the engineering education literature. This paper was inspired by a research project that examines the impact of non-cognitive factors on engineering student success (NSF #1626287). As part of this project, we developed a survey to measure several non-cognitive factors using existing validated instruments reported in the literature. Most non-cognitive factors relevant to thriving remain underexplored in the engineering education literature, suggesting a need to better understand and operationalize thriving for engineering

students. Thus, the topic of thriving is currently underexplored in Engineering Education and offers immense opportunities to enhance the success of the field.

The Unique Culture of Engineering Programs

Since thriving depends on culture and context, we hypothesize that engineering students perceive, understand, and experience thriving competencies in different ways from the populations for which general frameworks on thriving were developed. Our hypothesis is motivated by previous studies (Stevens et al., 2007; Lewis et al., 1998) that show engineering undergraduate students differ significantly from undergraduate students in other programs. Often, researchers study competencies based on their field's normative understanding of the particular competency. This approach can become problematic due to differences in the way that competencies are understood and operationalized in different fields. Thus, we base this engineering thriving framework on the assumption that engineering students require unique competencies to thrive that differ from those developed for other populations.

In many ways, the culture of engineering differs from that of other fields. In the context of this paper, engineering culture is defined as "the explicit and implicit customs and behaviors, norms, and values that are normative" in engineering education (National Academies of Sciences, Engineering, and Medicine, 2016, p. 60). This section situates engineering thriving in the unique engineering culture as described in the literature and its impact on engineering students.

The literature on engineering culture paints a grim picture—one where the successful engineering students are those who suffer the miseries of their education with pride (Stevens, Amos, Jocuns, & Garrison, 2007; Godfrey & Parker, 2010). The boot camp culture continues to pervade engineering education because of its military roots (Lohmann & Froyd, 2010). For example, Bucciarelli and Kuhn (1997) note that "there is rarely any serious attention given to the nature of the student experience" (p. 217). The underlying assumption appears to be that engineering education ought to be brutal. To exacerbate matters, engineering students are often expected to struggle from the prescribed heavy workloads and stressful situations, resulting in a boot camp mentality of "suffering and shared hardship" (Godfrey & Parker, 2010, p. 12). The culture in engineering has been especially negative for women (Tonso, 1996). For the most part, this grim worldview has crept into the culture of engineering education in the United States.

The 'suffering and shared hardship' culture of engineering is not conducive to engineering thriving, which we define as developing and refining competencies that contribute to successful engineering students with optimal functioning. Although engineering students might 'take the pain' for the sake of growth (Godfrey & Parker, 2010), psychologists know that prolonged durations of unmanaged stress rarely lead to positive development. Based on a series of studies started by O'Leary and Ickovics in 1995, people's response to high-stress situations (which they label 'adverse events') follows a normal distribution with four outcomes: thriving, resilience, survival, or succumbing. According to their model in Figure 1, the majority of people recover

and return to their previous level of functioning after experiencing a highly stressful adverse event. At one tail of the normal distribution, some people grow to a state of thriving with better functioning than before they experienced the adverse event. Similarly, some people at the other end of the normal distribution regress to a state of succumbing, with the inability to function properly without interventions. Overall, the majority of people are left surviving or recovering, with around the same functioning or worse than before they encountered the adverse event. As such, a boot camp culture of engineering education leaves little space for thriving.



Figure 1. Model of post-traumatic outcomes, adapted from O'Leary and Ickovics (1995)

The selective nature of those who thrive under a culture of adversity offers a perspective consistent with engineering's low retention rates, particularly for women and minorities. Research suggests that the culture of engineering education plays a large role in students' identities, engagement, and persistence in the major. For example, the culture of engineering contains overt and covert stereotypes that women and minority identities are less suitable for the profession (Cech and Waidzunas, 2011). This stereotype is so pervasive that only women and minorities in engineering majors who were able to redefine their identities persisted in the major (Hughes, 2012). The engineering culture even pervades to women and minorities in high school, who can be discouraged from pursuing STEM majors despite being highly competent in math and science courses (Ohland et al., 2008; Seymour and Hewitt, 1997). The ultimate effect of the negative engineering culture not only pushes away cognitively talented engineering students in college but also deters high school students from pursuing an engineering degree. As such, it is no surprise that women and minorities in engineering are more underrepresented than in other undergraduate majors (Anderson et al., 2006; National Research Council, 2011).

Overall, shifting the culture of undergraduate engineering from surviving to thriving can lead to more desired student outcomes in college, greater diversity, and post-graduate success. Research findings from positive psychology suggest that improving students' abilities to thrive also improve their academic performance, retention, engagement, and satisfaction (Durlak et al., 2011; Oades et al., 2011). Furthermore, since students' abilities to thrive in college strongly impact their abilities to thrive after college (The Gallup–Purdue Index Report, 2016), findings from this study demonstrate potential to support more engineers to thrive post-graduation.

Methods

Our proposed conceptual framework of engineering thriving contains several competencies based on a literature search of published research papers in Engineering Education, review of professional reports relevant to engineering education, and face validity checks with three faculty in Engineering Education. The first step in conceptualizing competencies relevant to engineering student success is to define what constitutes a "competency." In accordance with Passow's study of recent undergraduate engineering alumni, competencies are defined as "the knowledge, skills, abilities, attitudes, and other characteristics that enable a person to perform skillfully (i.e., to make sound decisions and take effective action) in complex and uncertain situations such as professional work, civic engagement, and personal life" (Passow, 2012, p. 97). The remainder of this section discusses the process we used to develop and scope the list of competencies in Table 1, followed by our process to connect and represent these competencies in a conceptual framework in Figure 3.

First, we reviewed a subset of existing literature in Engineering Education that focused on engineering student success. While searches for "thriving" proved ineffective in finding relevant research publications in Engineering Education, we collected a list of various academic and personal competencies that engineering education researchers identified as important for successful engineering. This list is summarized in a preliminary version of Table 1.

Second, we reviewed a subset of professional reports that highlighted competencies relevant to engineering student success, including ABET, National Science Foundation (NSF), the National Academy Press, and the National Academy of Science, Engineering, and Mathematics. Similar to our review of engineering education research papers, we expanded the list of academic and personal competencies that these reports argued as crucial for successful professional engineering or STEM careers. Furthermore, we refined personal competencies based on interpersonal and intrapersonal competencies to better align with existing frameworks of categorizing non-cognitive competencies (National Academies of Sciences, Engineering, and Medicine, 2017, p. 1). We expanded Table 1 to its second iteration by incorporating a summary of competencies from our review of professional reports.

Next, we reviewed the next three iterations of this list of competencies with several engineering education faculty for face validity checks. Based on their feedback and informal conversations, we further refined the conceptual framework of engineering thriving to include more competencies that we missed from our literature search and review of professional reports, such as positive health and emotions. We discuss these competencies in more detail in the future research section. These competencies include Overall, this final step of checking with faculty expanded the competencies listed in Table 1 to its fifth iteration.

The next step was to scope the extensive list of competencies in Table 1 based on our goals for the conceptual framework of engineering thriving. Since the goal of our framework is to broaden success metrics for undergraduate engineering students beyond just academic competencies, we decided to include only the competencies that had existing survey instruments with evidence of validity and reliability. This selection criterion scoped the list of final competencies in Table 1 to only those which can be measured, resulting in our final iteration of Table 1.

While Table 1 provides a summary of engineering education literature search findings, professional reports, and validity checks with faculty, the list in Table 1 is neither exhaustive nor final. Rather, this list serves as the first attempt to operationalize various academic and personal competencies relevant to thriving in the engineering context. Described in more detail in the Future Research section, more research is needed to refine and validate this conceptual framework for engineering thriving.

Table 1. Competencies important to engineering student success, as identified in published research papers in Engineering Education and professional reports (such as ABET and NSF)

Competency	Definition
Competency	
Academic Self-efficacy	A student's belief that he or she can succeed in academic tasks in the engineering major (Jones et al., 2010)
Communication	Oral, written, and graphical skills that help engineers effectively convey ideas (Shuman, Besterfield-Sacre, & McGourty, 2005; ABET Criterion 3g)
	Can be facilitated through cooperative learning (Felder, Woods, Stice, & Rugarcia, 2000)
Conscientiousness	Behaviors related to self-control, responsibility, hard work, persistence, and achievement orientation (Roberts et al., 2014)
Disciplinary and Technical Knowledge	an ability to apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require application of principles and practical knowledge (ABET Criterion 3a,k)
GPA	Undergraduate students grade point average, usually cumulative GPA is considered when measuring academic success in engineering programs (French, Immekus, & Oakes, 2004)
Graduation	Completion of engineering degree, usually four years until undergraduate graduation are considered "on time" (National Academy of Engineering Committee, 2005)
Growth Mindset	A student's belief that his or her own intelligence (or any other important personal attribute) is not a fixed entity but a malleable quality that can grow and improve; Promotes higher achievement and persistence for students in STEM fields (Hill, Corbett, & Rose, 2010)
Identity	The ways in which students describe themselves and are positioned by others in the role of being an engineer (Godwin, 2016; Brickhouse, Lowery, & Schultz, 2000; Varelas, 2012) including both collective and invidual components, mediated by social circumstances (Tonso, 2014); Can be contexualized as: interest in the subject, perceived recognition by others, and performance/competence beliefs (Godwin, 2016; Carlone & Johnson, 2007; Hazari et al., 2010); Might be precursor to motivation (Oyserman, Elmore, & Smith, 2012).
Lifelong Learning	An understanding of the need for and an ability to engage in life-long learning (ABET Criteria 3i)
Intrinsic Goals, Motivation, and Interest	Personal goals and values that a student experiences as rewarding or meaningful in and of themselves, linked to strong interest; "Motivation that stems from primarily internal reasons" (Chyung, Moll, Berg, 2010; National Academy of Sciences, Engineering, and Medicine, 2017), and includes characteristics of persistence, goal activities and medicines (Boardure, 1007)
Positive Future Self	A positive image, picture, imagined trajectory, or personal narrative that a student constructs to represent what kind of person he or she will be in the future (National Academy of Sciences, Engineering, and Medicine, 2017)
Prosocial Goals and Values	Personal goals and values aimed at helping others, furthering goals/values of a group or society as a whole, or promoting a prosocial religious or political agenda or some other endeavor that transcends self-interest (National Academy Press; Jones et al. 2010)
Retention	Continued enrollment in the engineering major (French, Immekus, & Oakes, 2005)
Sense of Belonging	A student's sense that he or she belongs, fits in well, or is socially integrated at college (Strayhorn, 2012)
Societal/Global Awareness	a knowledge of the impact of engineering technology solutions in a societal and global context (ABET Criterion 3h i)
Solving Engineering Problems	an ability to identify, formulate, and solve defined engineering problems (ABET Criterion 3e); often by designing and condicting experiments under constraints (ABET Criterion 3b,c)
Teamwork	the ability to lead and work effectively as part of a larger group (Shuman, Besterfield-Sacre, & McGourty, 2005), particularly multidisciplinary teams (ABET Criterion 3d)
Utility Goals and Values	Personal goals and values that a student perceives as directly linked to the achievement of a desired end in the future (National Academy of Sciences, Engineering, and Medicine, 2017)

Once we completed the list in Table 1, we categorized and represented these competencies in a visual diagram of engineering thriving over the course of ten iterations. The challenge to creating a visual diagram of engineering thriving is due to the largely underexplored nature of positive interpersonal and intrapersonal competencies that support engineering students to function optimally as engineers. Not only does research on engineering students' positive personal competencies pale in comparison to their academic struggles, but also the few publications we found on this topic seem to occur among isolated lines of research. Overall, the underexplored nature of positive competencies that contribute to engineering student success clouds the bigger picture of important competencies and the relationships among them.

To categorize the list of competencies determined in Table 1, we referred to the taxonomy used by the National Academies of Sciences, Engineering, and Medicine. According to these National Academies, the three core categories of competencies and their definitions include:

- *Intrapersonal competencies* involve self-management and the ability to regulate one's behavior and emotions to reach goals.
- *Interpersonal competencies* involve expressing information to others as well as interpreting others' messages and responding appropriately.
- *Cognitive competencies* involve thinking, reasoning, and related skills. (National Academies of Sciences, Engineering, and Medicine, p. 1)

In our proposed framework of engineering thriving, we expanded "cognitive competencies" to include engineering education narratives around traditional academic measures of success in engineering programs. We called this expanded category "academic competencies". While the National Academies' three core categories encompassed the majority of competencies we listed in Table 1, it leaves out the breadth and depth of narratives in the field around academic measures of success commonly used to operationalize success in engineering programs, such as GPA, retention, and graduation.

Given the underexplored nature of categorizing competencies in Engineering Education, we explored diagrams of conceptual frameworks with competencies of human thriving from other fields. Fields such as Positive Psychology, Positive Education, and Human Development have published frameworks on thriving in larger numbers of scholarly publications. Based on our search of literature from Psychology and Human Development, we designed our diagram of engineering thriving based on insights from Norrish's (2013) framework of Positive Education and Maslow's (1970) hierarchy of needs. We selected these two scholars' diagrams for reference because they closely reflect the goals of our conceptual framework for engineering thriving. For example, both Norrish's and Maslow's diagrams are based on the theories of optimal human functioning, connect several competencies studied in depth by other researchers, are measurable, and apply to educational settings. Figure 2 illustrates these two diagrams of human thriving.



Figure 2. Visual representation of Positive Education, adapted from Norrish (2013) and Maslow's Hierarchy of Needs, adapted from Maslow (1970).

Next, we reviewed Norrish's and Maslow's justifications for their visual frameworks of human thriving and adapted the aspects that best applied to our conceptual framework. To start, we examined the similarities and differences in the ways these other scholars represented human competencies. We noticed that both scholars included the "thriving" component at the top of their diagram despite describing flourishing and self-actualization as ongoing processes and not end goals. Furthermore, both scholars represent their main competencies in distinct categories from each other. Many positive psychology researchers group together the competencies that are highly correlated to reduce redundancies in their frameworks. Finally, both scholars included competencies that reflect those determined in engineering thriving, including achievement (such as academic performance or mastering skills), interpersonal (such as relationships with others), and intrapersonal (such as engagement or interest).

From this analysis, we designed ten iterations of the conceptual framework of engineering thriving. We edited each iteration of the visual diagram based on feedback from engineering education faculty, informal conversations with undergraduate engineering students, and comments from reviewers. Our current diagram of engineering thriving is illustrated in Figure 3 and unpacked in the following section.

Although our visual framework of engineering thriving is based on conceptual frameworks of human thriving from other fields and cross-checked with several engineering education faculty and engineering students, this version of the conceptual framework of engineering thriving serves as the first attempt to visually represent a concept that is currently underexplored in

Engineering Education. Although grounded in engineering education narratives, Figure 3 is not a final conceptual framework of engineering thriving. Described in more detail in the Future Research section, more research is needed to refine this conceptual framework of engineering thriving.

Conceptual Framework of Engineering Thriving

After reviewing literature and professional reports from Engineering Education, defining key competencies, categorizing individual competencies into three core competencies, and examining the visual representations of thriving from other fields, Figure 3 represents a framework for engineering thriving. The remainder of this section unpacks the engineering thriving conceptual framework shown in Figure 3.



Figure 3. Conceptualization of Engineering Thriving. This framework represents individual competencies of thriving relevant to undergraduate engineering students.

Unpacking the Engineering Thriving Framework

The overall structure of the engineering thriving framework is hierarchical, representing a taxonomy of distinct competencies, tied together by engineering culture, that support

undergraduate engineering students to thrive. At the top of the framework is engineering thriving, contextually defined as growing and refining competencies relevant to successful, optimally functioning engineering students. All competencies that comprise engineering thriving can be taught, learned, and measured in the classroom.

Consistent with Norrish's and Maslow's frameworks, we represent engineering thriving at the top of the diagram to illustrate its importance as the focus of continuously building academic, intrapersonal, and interpersonal competencies. Just like Norrish's and Maslow's frameworks, engineering thriving is an approach and continuous process shaped by individual, community, and cultural factors, as opposed to a discrete goal to be achieved then archived. Since engineering thriving is a malleable construct that evolves over time, developing thriving engineers depends on continuously growing and refining their repertoire of competencies for current situations and new pursuits or unexpected challenges. Overall, thriving is not about achieving perfection or meeting a set of pre-requisite standards but rather developing and refining one's academic and personal functioning. This approach to conceptualizing thriving is consistent with Seligman's (2013) claim that interventions which mitigate problems differ from those that foster thriving.

Below engineering thriving consists of the list of competencies determined in Table 1, grouped into the three broader categories of competencies adapted from the taxonomy used by the National Academies of Sciences, Engineering, and Medicine. We encircle these three groups of competencies with engineering culture to illustrate that engineering culture provides the foundation and environment that determines the customs, behaviors, norms, and values that either promote or undermine competencies. The double arrows indicate that some components of these three main categories of competencies seem close related and complementary, such as engineering identity, belongingness, and retention. For example, research on identity reveals correlations with students' interest (intrapersonal), sense of belongingness (interpersonal), and retention (academic) (Perez, Cromley, & Kaplan, 2014; Godwin, 2016; Pierrakos, Beam, Constantz, Johri, & Anderson, 2009; Wolffram, Derboven, & Winker, 2009; Strayhorn, 2012). However, the large majority of extant research on the interpersonal and intrapersonal competencies seem to occur in disparate lines of research. This framework for engineering thriving can serve to unite these disparate lines of research by determining the strength of correlations between competencies.

The "Engineering" in Engineering Thriving

Some might wonder how engineering thriving differs from frameworks of thriving from other fields. Although many conceptual frameworks for thriving exist from other fields, these existing frameworks seem to poorly generalize to engineering students. For example, after collecting

preliminary data from 490 undergraduate engineering students, exploratory factor analysis (EFA) did not produce a factor structure consistent with previous reports for several competencies such as engagement, subjective wellbeing (positive emotions), and relationship support and respect (paper in review). Given the survey questions on thriving showed evidence of strong internal consistency in a broad higher education population (Su, Tay, & Diener, 2014), it is unlikely that flaws in the survey questions led to these poor EFA results. Rather, one potential explanation for these poor EFA results is that current frameworks of thriving, which were not developed specifically for undergraduate engineering students, may not fully apply to this population. Overall, these preliminary findings seem to suggest a need to develop a conceptual framework of thriving that is relevant to engineering students.

To address the need for a framework relevant to engineering students, our entire research and development of the competencies that comprise engineering thriving is grounded in engineering education literature, professional reports, and feedback from faculty in the field and undergraduate engineering students. While this engineering thriving framework is developed from existing narratives in Engineering Education, several competencies appear to overlap with frameworks of human thriving from other fields. Table 2 summarizes the main competencies associated with thriving, based on Norrish's (2013) framework of Positive Education. These competencies were developed based on a school in Australia with principles of Positive Psychology embedded in its K-12 curriculum.

Table 2

Competencies important to student thriving from Positive Education, adapted from the Positive Education framework (Norrish et al., 2013).

Competency	Definition
Positive Emotion	Students' capacities to anticipate, initiate, experience, prolong, and build positive emotional experiences.
Positive engagement	Living a life high in interest, curiosity, and absorption, and pursuing goals with determination and vitality
	Flow is conceptualized as the peak experience of engagement when people are most immersed, focused, and energised (Bakker, 2005)
	Is cultivated by nurturing intrinsic motivation (Norrish, Williams, O'Connor, & Robinson, 2013)
Positive accomplishment	development of individual potential through striving for and achieving meaningful outcomes, and involves the capacity to work towards valued goals, the motivation to persist despite challenges and setbacks, and the achievement of competence and success in important life domains.
	Is cultivated by adopting a growth mindset Dweck, especially through praised focused on effort and persistence (2006)
Positive purpose	The intrinsic value of contributing to others and the community, something larger than oneself (Seligman, 2011); Purpose provides people with a central mission or vision for life and a sense of directedness (Ryff & Keyes, 1995).
	Cultivated by acting in accord with one's values (Waterman, Schwartz, & Conti, 2008) and using signature strengths in the service of others (Peterson, Park, & Seligman, 2005)
Positive relationships	Create and maintain strong and nourishing relationships with self and others
	Cultivated by building social and emotional skills
Positive health	Practicing sustainable habits for optimal physical (diet, sleep, exercise) and psychological (resilence) health
Character Strengths	A ubiquitously recognized subset of personality traits that are morally valued (Peterson & Seligman, 2004)

While several competencies from Engineering Thriving (in Table 1) and Positive Education (in Table 2) appear to overlap, they fundamentally differ based on the target populations, institutional cultures, and intended purpose from which they were developed. The following paragraphs describe each component in more detail.

First, each conceptual framework on thriving is specific to the population from which it was created. For example, Norrish's conceptual framework of Positive Education is based on studies from K-12 students from a school in Australia (Norrish, 2013). Norrish acknowledges that more research is needed to explore how positive education translates to other settings (p. 156). Similarly, Maslow's hierarchy of needs is based on Maslow's biographical analysis of 18 people that he determined were self-actualized, such as Albert Einstein and Abraham Lincoln (Maslow, 1970). Maslow's hierarchy of needs has been criticized for being developed based on a limited and highly biased sample of elite individuals and may not generalize to the larger population (Fallatah & Syed, 2018). More generally, Positive Psychology researchers have created several conceptual frameworks on thriving based on studies with European American populations,

resulting in critiques such as "many conceptualizations of optimal psychological functioning and well-being are of limited applicability to people of color" (Utsey, Hook, Fischer, & Belvet, 2008, p. 207). Overall, different populations tend to have unique understandings and experiences of thriving and, thus, existing frameworks for specific populations likely do not generalize to other populations.

Second, culture influences which competencies contribute to thriving as well as how we operationalize those competencies. Pedrotti (2014) notes that different populations define, manifest, and interact with competencies uniquely based on the influence of culture (p. 403). In fact, several positive psychology researchers acknowledge that conceptual frameworks on thriving are culturally biased when determining which competencies are considered strengths (Ho et al. 2014, Pedrotti, 2014). Cultural biases limit the generalizability of conceptual frameworks of thriving to other populations with different cultures than that which the frameworks were developed.

Expanding on our discussion of engineering culture, engineering students face unique experiences and curriculum demands that differ from those of students in other majors (Veenstra, Dey, & Herrin, 2008). This unique culture of engineering leads researchers to study "engineering identity" as an intrapersonal competency unique to engineering students even though identity research spans several fields of study. For example, studies indicate that students' abilities to develop engineering identities prior to college predict their likelihood of choosing an engineering major (Godwin, 2016). The unique culture of engineering programs shapes an 'engineering identity' that can welcome or deter potential undergraduate engineering students. Furthermore, engineering students who retain until graduation maintain strong engineering identities over the course of their education (Prybutok et al., 2016). Just as engineering education literature recognizes engineering identity as unique from general research on identity (Tonso, 2014), other competencies in the framework for engineering thriving are also operationalized differently than their counterparts from other fields of study. Broadly speaking, the unique curricula demands of undergraduate engineering programs (Veenstra, Dey, & Herrin, 2008) shape a unique definition of academic success in undergraduate engineering students which differs from that of other fields. More specifically, engineering education values a "core curriculum" which typically includes chains of prerequisite technical classes that emphasize problem solving and critical thinking skills (Crawley et al., 2007; ABET Criterion 3a,c,e, 2011). Furthermore, Crawley et al. (2007) argue that the need to "bridge the divide" between engineering's "rigid focus on core curriculum" and the more flexible, general, practical knowledge emphasized in other fields (p. 235). Overall, engineering culture shapes, promotes, and undermines a unique set of competencies specific to engineering student thriving.

Third, one intended purpose of this framework of engineering thriving is to unite disparate lines of research in Engineering Education. While the prevailing narratives on undergraduate

engineering student success revolve around academic and cognitive challenges, engineering education researchers might not be as aware of the narratives regarding their non-cognitive strengths. Coming from diverse disciplinary backgrounds, the community of engineering education researchers might not have a common language to describe similar competencies relevant to engineering student thriving. Thus, we developed this conceptual framework for engineering thriving to unite engineering education researchers working in disparate lines of research focused on supporting engineering students to succeed.

Overall, the engineering thriving we propose in this paper differs from other frameworks of thriving due to the unique experiences of undergraduate engineering students, the unique culture of undergraduate engineering, and the intended purpose of this conceptual framework of engineering thriving. This conceptual framework for engineering thriving is a first attempt to operationalize the competencies that contribute to optimally functioning engineering students. We discuss several opportunities to improve this conceptual framework for engineering thriving in the following section on future research.

Future Research

First, the competencies for thriving from other fields that do not overlap with those from Engineering Education provide insights into areas for future research. For example, positive health and emotions are competencies recognized as vital to thriving in Positive Education (Norrish, 2013). However, positive health and emotions are neither as well-researched nor discussed in the same ways in Engineering Education. As such, drawing upon the vast literature on positive health and emotions from Positive Education or Positive Psychology can provide insights for engineering education researchers to explore additional competencies that might support more engineering students to thrive.

Second, most existing research on engineering students' personal competencies and their success consist of correlational analyses, while intervention studies on undergraduate engineering populations are currently scant. In fact, Guilford et al. (2015) explicitly acknowledge that "in engineering education, pre-post quantitative comparisons of these psychological constructs in response to instructional interventions appear to be wholly lacking" (p. 1). The National Academies of Sciences, Engineering, and Medicine echo Guilford et al.'s claim in their 2017 report, stating that "there is a paucity of evidence on the possible relationships between intra- and interpersonal competencies and the success of students intending to major in science, technology, engineering, and mathematics fields" (p. 72). Overall, the largely underexplored studies on thriving competencies for engineering education populations conceal the relationships between competencies that support engineering students to thrive.

Consistent with the underexplored nature of thriving in undergraduate engineering student populations, uniting previously disparate lines of research would offer insights into the big picture of engineering thriving. For example, we know that students who perceive themselves as thriving generally perform better academically and personally. But so, too, does academic and personal success contribute to a students' perception of thriving. This relationship between thriving and succeeding at competencies appears to be bi-directional for general frameworks of thriving. However, this relationship is underexplored in the context of undergraduate engineering students. Furthermore, a robust conceptual framework should comprise independent competencies. In other words, the competencies that are highly inter-correlated should be grouped together to reduce redundancy and improve convergent validity. Thus, more studies examining the intercorrelations of competencies will likely elucidate the bigger picture of engineering thriving and unite current disparate lines of research.

Overall, more research is needed to rigorously test this conceptual framework of engineering thriving for diverse engineering students. Additional research involving empirical studies, statistical analyses, and qualitative studies are imperative to refining and improving our understanding of engineering thriving.

Conclusion

Cultivating thriving in engineering students and institutions holds enormous promise for the future of engineering education. The growing body of evidence suggests thriving impacts students' GPA, retention, resilience, and life success post-graduation. This evidence suggests that thriving might be the critical, yet unexplored, link to support more undergraduate engineering students to reach their highest potential in engineering school and beyond.

While this first attempt at a conceptual framework of engineering thriving is neither exhaustive nor final, it is intended to facilitate the initial discussions and ideas for research to develop a more robust and fine-tuned framework. The competencies in this conceptual framework result from piecing together findings from a literature search from Engineering Education research, review of professional reports relevant to engineering education, and face validity checks with engineering faculty. Future steps to validate and refine this conceptual framework for engineering thriving include incorporating data from empirical studies.

A thriving future for engineering education starts with engineering students. Engineering Education has front row seat to the future—one that can foster thriving engineering students whose work shapes the future of our society and world at large. The goal of this paper is to begin

conversations toward a new paradigm for engineering education—one that educates future engineers to not only make a living but also make life worth living for themselves and others.

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