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What Most Facilitates Thriving for Undergraduate Engineering Students? A Rank Order Investigation of Engineering Experts

Julianna Gesun

Julianna Gesun, Ph.D., is currently a National Science Foundation/American Society for Engineering Education engineering postdoctoral fellow and postdoctoral diversity and innovations scholar in the Department of Mechanical Engineering at the University of New Hampshire. Her research focuses on discovering and understanding strength factors that contribute to more thriving undergraduate engineering students and aspects of engineering culture and contexts that support thriving. Her research interests intersect the fields of positive psychology, engineering education, and human development to understand the intrapersonal, cognitive, social, behavioral, contextual, cultural, and outcomes factors that influence thriving in engineering. She received her Ph.D. in Engineering Education at Purdue University, where she was an NSF Graduate Research Fellow and the winner of Purdue's 2021 Three Minute Thesis competition for her work in developing research and courses on engineering thriving. She also received dual bachelor's degrees in Industrial Engineering and Human Development and Family Studies at the University of Illinois at Urbana-Champaign. Her prior work experiences include product management, consulting, tutoring, marketing, and information technology.

Julia Rizzo

Julia Rizzo graduated from the University of New Hampshire in December 2021 with a B.A in Psychology. She is currently working in research under Dr. Gesun in discovering factors important to promoting thriving in engineering undergraduate students. Julia is extremely interested in education, learning, and research as she wishes to continue her education and obtain a M.A. in the field of School Psychology. Julia's research interests include understanding complex family systems and the role the family plays in a child's ability to succeed. By working with Dr. Gesun and her research interests, Julia is able to understand thriving from an alternative perspective, which will aide her in future work.

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Abstract

This research paper explores engineering experts' perceptions of the most important factors of thriving for undergraduate engineering students. Faculty, staff, and members of the engineering education system play a vital role in creating environments, and forming relationships with students conducive to thriving. The study in this paper builds upon prior work on engineering thriving that identified 147 factors developed from a literature review, refined with expert consultation. Out of the long list of factors, little is known regarding the most important factors that can serve as a starting point for engineering experts with limited resources to create environments and relationships that support more thriving engineering students.

In this paper, we analyze ranked order data to investigate the most important internal thriving competencies. Participants include 47 engineering experts i.e., engineering administrators, professors, staff, and advisers. To find which competencies were perceived as most important to engineering thriving, each expert was asked to generate and define up to ten competencies that they considered to be most important, then rank these competencies in order of importance. During data analysis, ranked competencies were scored on a reverse ordinal points basis, with the most important rankings receiving 10 points and the least important rankings receiving 1 point.

Overall, the top five most important competencies were Communication/Listening Skills (overall score = 104), Help-seeking/ Resourcefulness (overall score = 104), Teamwork (overall score = 97), Time Management (overall score = 96), and Resilience (overall score = 95). Findings from this study highlight the importance of intrapersonal, social, and behavioral competencies, providing a starting point for future work developing a survey of thriving for engineering students. Furthermore, these findings provide a greater insight into which high-impact competencies engineering faculty, staff, and administrators can focus on when creating environments conducive to student thriving and interacting directly with students when teaching, supporting, advising, and mentoring.

Introduction

Although products of engineering reach nearly every facet of society, little is known regarding the most important factors that contribute to thriving for undergraduate engineering students who will supply the engineering workforce. In this paper, we build upon prior work [1] that defines e*ngineering thriving* as a process in which students develop internal competencies and manage changing external factors within the broader engineering education system and culture. A model of engineering thriving has been developed from a literature review and refined in consultation with experts [2]. This model accounts for 147 total factors of thriving, which span across three broader categories:

1) Internal thriving competencies, which are defined as behavioral, social, intrapersonal, and cognitive "knowledge, skills, abilities, attitudes, and other characteristics" that support thriving engineering students [2], [3]. Examples include behaviors, social skills, and motivation, and spatial ability;
2) External thriving outcomes, which are defined as "the results and impacts of the use of internal competencies under favorable contexts, situations, and systemic factors" [2]. Examples include health, grades, community, and character;
3) Engineering culture, systemic factors, resources, context, and situation, which are defined as "the personal and university contexts, situations, resources and cultures that impact engineering students' internal competencies and external outcomes" [2]. Examples include accessibility, personal implicit bias, availability of scholarships, and departmental climate.

The purpose of this study is to investigate the most important internal thriving competencies that engineering experts (such as faculty, staff, and administrators) must consider when supporting more thriving engineering students. We target the population of engineering faculty, staff, and administrators as these members play a vital role in fostering environments and forming relationships with students that facilitate thriving [4]. These members of the engineering education system directly impact students' experiences in engineering programs and "are individually and collectively responsible for shaping the cultural and systemic factors of the engineering program and institution" [2]. Moreover, these members influence and create the long-standing engineering culture and relationships with students which directly affect their thriving. Thus, this study focuses on perspectives from these longer-term members of the engineering education system who self-identify as invested in engineering student thriving.

Methods

To scope the extensive list of 147 factors captured in the three broader categories in the model of engineering thriving, this paper reports a study that exclusively focuses on internal thriving competencies. Data for this study were collected during the first phase of a three-phase data collection process as part of a larger project to create a model of engineering thriving by gathering consensus from engineering experts [2]. We acknowledge that thriving for engineering students includes a breadth of interactions between the students and their environment within the larger engineering culture and system. From a research perspective, best practices when conducting rank-order research caution against asking participants to rank a list of 147 factors because "distinctions between individual elements become difficult for the person making the

ranking to maintain meaning" [5]. To scope the analysis for this paper, each participant was asked to rank no more than ten internal thriving competencies in order of importance.

Participants

Faculty, staff, and administrators play a vital role in creating environments conducive to thriving and forming relationships with students that facilitate or impede thriving. Yet, almost none of these members publish their insights on engineering student thriving in the research literature on engineering student success and thriving [1]. Thus, we were interested in capturing this population's expertise on supporting engineering student thriving. In this study, we define "expertise" in alignment with Geier's recommendation to recruit "the individuals involved in the work rather than a selected panel of experts" [6]. p. 390. In this study, experts consisted of engineering faculty, instructors, administrators, academic advisors, and others who self-identified as invested in engineering student thriving and satisfied three eligibility criteria;

1) Experts must have worked at, or were associated with, an undergraduate engineering program at an academic institution, such as a university or college. This criterion was essential as the target audience for this study is undergraduate engineering students.
2) Experts must have taught, supported, advised, mentored, served in an administrative role, and/or otherwise worked directly with undergraduate engineering students. This criterion was developed to select professionals who were truly working directly with undergraduate engineering students in some capacity.
3) Experts must have had at least three years of experience with undergraduate engineering students.

In our study, Mechanical Engineering and Bioengineering/Biomedical Engineering were the most represented disciplines. Our sample captured fewer perspectives from engineering staff, directors, and department chairs. For those listed as faculty, our experts self-reported as primarily research-focused (45%) or teaching-focused (32%). Despite these categories, research faculty also likely had some teaching responsibilities, and teaching faculty may have been involved with professional activities beyond teaching. The experts represented an even balance of experience, with 36% having 3-10 years, 26% having 10-20 years, and 38% having over 20 years of experience. The experts represented 23 academic institutions, 15 academic disciplines, three administrative offices, nine position types, and between 3-20+ years of experience. For more detailed information about the demographic attributes of the participants, please refer to the larger study reported in [2].

Convenience and snowball sampling [7] were used at the 2019 American Society for Engineering Education (ASEE) Annual Conference and Exposition to select a group of engineering experts with varied backgrounds and experiences who are invested in supporting more thriving engineering students [8]. A Qualtrics link to an initial survey was sent to the chair of each ASEE division, where they were asked to share the link with their division's listserv, along with word-of-mouth recruitment during the conference. Potential experts were asked at the beginning of the study to commit to all rounds of the research study and to share the recruitment link with colleagues who met the eligibility criteria. The general guideline for participant size is

15 to 30 experts [9]. Of the 72 participants who completed the initial survey, 47 participants met our eligibility criteria and participated in this study.

Procedures for Data Collection & Analysis

To identify the competencies most important to engineering thriving, an electronic survey was developed on Qualtrics with an open-ended test protocol. The first survey question, "How do you define thriving for undergraduate engineering students (not engineers in professional workplaces)?" was rated on an open-ended response scale, allowing for a general understanding of how the individual understands thriving. Although this question was not relevant to the data analysis for this study, it was used to prompt the second survey question, "Given this definition, please list the most important competencies for undergraduate engineering students to thrive. Include a short definition for each competency you listed." In alignment with best practices, participants were only given enough space to identify and describe up to ten competencies [5]. Once participants completed this question, they were asked to rank the competencies they listed in order of importance (with #1 as the most important). Participants' confidentiality was assured throughout the process of conducting this IRB-approved research protocol. Synonymous terms were combined when the terms and definitions used similar words to describe a competency. For example, “teamwork,” “work in teams,” “working well with others in teams,” and “effectively work and live with others in teams” were all coded as “teamwork.” The list of top 10 competencies in **Table 1** was generated based on the responses given by participants in response to these survey questions. For each of the top 10 competencies, we also report the minimum ranking, lower quartile, median, upper quartile, maximum, and the total number of participants who ranked each competency. This information is represented in the box and whisker plot in **Figure 1**.

Reverse ordinal ranking was done as a measure of validity to express the value of each ranking, ensuring the competencies ranked highest would remain high in value in comparison to the competencies ranked lower. Thus, the authors gave 10 points to the competency the expert considered to be most important (ranked as #1), 1 point to the competency the expert considered 10^{th} most important (ranked as #10). Then, points associated with all the rankings were summed for each individual competency to produce the Overall Score shown in **Table 1**.

Results

As shown in **Table 1**, the most frequently ranked competencies tended to receive the highest overall scores. Communication/ Listening Skills (overall score = 104) and Help-seeking/ Resourcefulness (overall score= 104) were deemed the most important competencies, followed by Teamwork (overall score = 97), Time Management (overall score = 96), and Resilience (overall score = 95). A complete table of ranked competencies is captured in **Appendix A**, which shows the four competencies ranked lowest were Networking Skills (overall score = 3), followed by Empathy (overall score = 4), Open Mindedness (overall score = 4), and Visualization (overall score=4). As all competencies listed by experts are perceived to be important and have received consensus as critical to engineering thriving, the lowest rankings do not imply lack of

importance. Rather, a lower overall rank indicates fewer experts reported and ranked that competency.

Table 1

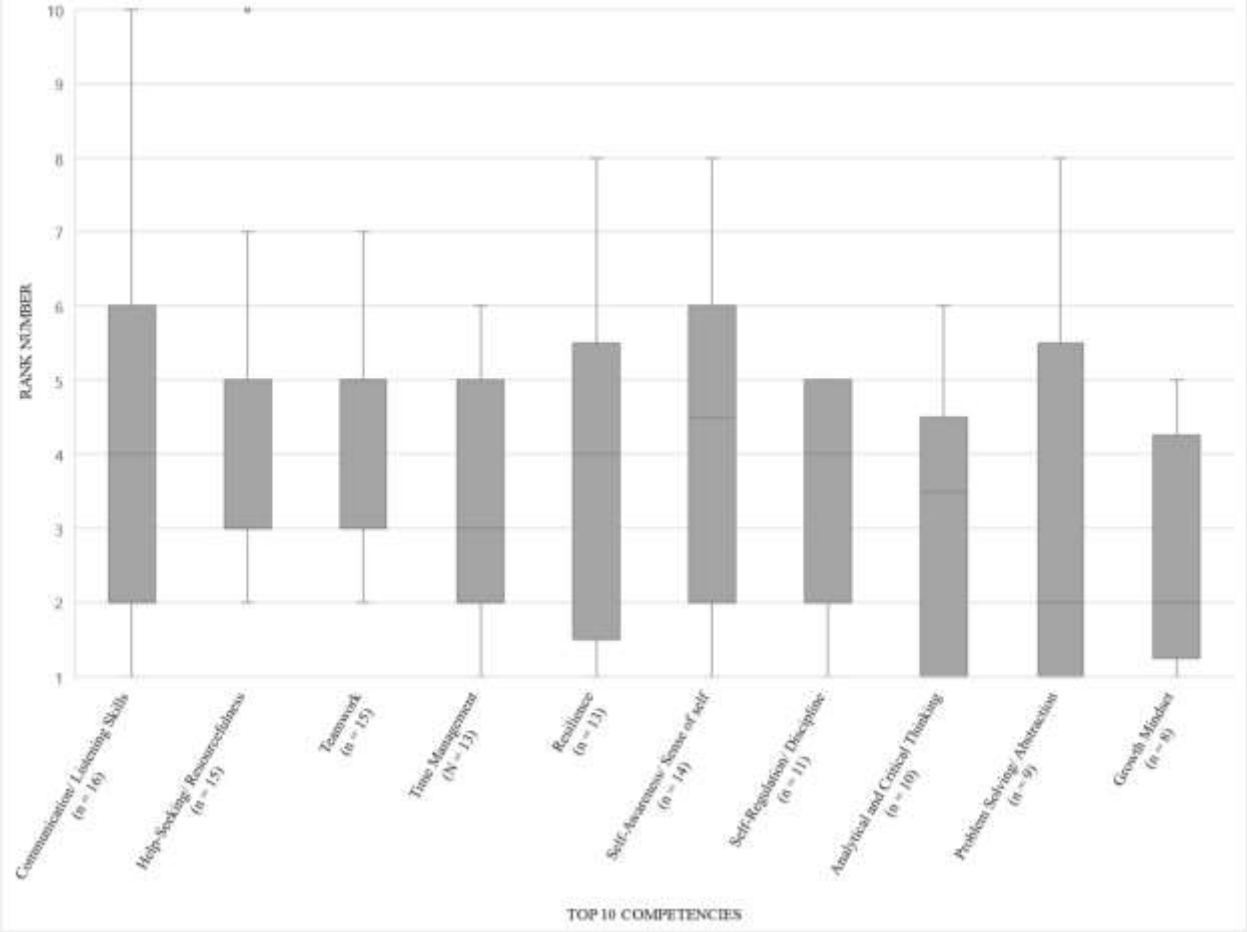
Overall Scores of Competencies Ranked Top 10

Competency	Overall Score	Overall Rank
Communication/ Listening Skills	104	1=
Help-Seeking/ Resourcefulness	104	1=
Teamwork	97	3
Time Management	96	4
Resilience	95	5
Self-Awareness/ Sense of self	94	6
Self-Regulation/ Discipline	82	7
Analytical and Critical Thinking	78	8
Problem Solving/ Abstraction	71	9
Growth Mindset	68	10

Figure 1 provides nuance into the wide range of individual perspectives about the value of the relative importance of the top 10 competencies shown in **Table 1**. For example, Communication/Listening Skills and Help-Seeking/Resourcefulness received the highest overall score (104). However, Communication/ Listening Skills has a much greater range of responses (min = 1, max = 10, interquartile range = 4) compared with Help-Seeking/Resourcefulness (min = 2, max = 7, interquartile range = 2). The rankings for Help-Seeking/Resourcefulness show the same distribution as rankings for Teamwork, except Help-Seeking/ Resourcefulness has one outlier of 10, which added additional points to the overall score. All competencies have a maximum ranking of at least 5 and all but two competencies (Help-Seeking/Resourcefulness and Teamwork) have a minimum ranking of 1. These individual variations in rankings are not captured in the single "overall score" presented for each competency in **Table 1**, because the most frequently ranked competencies received higher overalls scores than those individually ranked as the most important by a few participants.

Figure 1

Box and whisker plot of top ten competencies



Trustworthiness

Lincoln and Guba's criteria [10] were followed to ensure trustworthiness in data analysis. Prior to data analysis, all personally identifiable information was removed from the data. Credibility and transparency were established as the authors met to resolve discrepancies in coding competencies. For example, the raw data from one participant stated the following competency and definition: “time management, effectively organize and planning tasks to achieve a goal.” This data was coded as “time management” by one author and “achieving goals” by another author. To resolve this discrepancy, the authors discussed that “achieve a goal” only showed up in the definition to illustrate a positive outcome of time management, rather than illustrating the importance of another competency. Thus, the authors agreed that the code “time management” represented the raw data better than “achieving goals.” Records were kept at each stage of data analysis, including raw data, decisions made, and the final steps in the ranking procedure. For evidence of the reliability of the data analysis, the second author completed each step of the procedure three times and the total procedure twice. The data were then reviewed independently

by the first author, and all discrepancies were reviewed a fourth time with both authors and discussed until an agreement was reached.

Discussion

This study extends upon prior research of engineering thriving by further investigating internal thriving competencies. These competencies are to be considered by experts when fostering environments and relationships that facilitate engineering student thriving. As faculty, staff, and members of the engineering education system play a vital role in creating these environments conducive to student thriving, targeting the feedback of engineering experts is crucial.

While all competencies identified by the experts are important in creating environments conducive to students thriving in engineering, the engineering experts considered behavioral, social, and intrapersonal competencies more important than cognitive competencies in promoting thriving engineering students. As shown in **Table 1**, the top five rankings encompass social (Communication/Listening Skills, Teamwork), behavioral (Time Management, Help-Seeking/Resourcefulness), and intrapersonal (Resilience) competencies, while the first cognitive competency did not show up until rank #8 (Analytical and Critical Thinking). This finding contrasts with the broader literature in the field which tends to focus on cognitive competencies that support engineering students' academic success (such as retention or academic performance) [1]. Expanding the scholarly narrative of supporting cognitive competencies is a crucial step toward a multidimensional view of engineering student thriving that accounts for more variation in students' outcomes than can be explained by just cognitive competencies.

Relative to the 101-point difference in overall scores between the highest ranked competency and lowest ranked competency, the discrepancy in overall scores among the top five ranked competencies was surprisingly marginal (10 points), especially noting that the experts could list up to ten of any competencies that came to mind. The top five most important competencies contained a tie for the highest ranked and the overall scores between ranks #3 and #6 only differed by three points (see **Table 1**). An explanation for this similarity in overall points is that competencies such as Communication and Teamwork are relatively more studied in the engineering education research community than other competencies. For example, these competencies are also present in the ABET criteria for student outcomes [11] and the National Academy of Engineering's key factors for engineering student success in meeting the grand challenges [12]. Thus, these competencies may already be common discourse within the engineering education community, thus our experts were more familiar with these terms.

A surprising finding is that the competencies ranked with the highest overall scores were not necessarily ranked on the top of the list for individual participants, indicating a wide range of individual perspectives about the relative importance of individual competencies. Communication/Listening Skills and Help Seeking/Resourcefulness both received the highest overall scores (104 points), but the median ranking was #4 and #3, respectively (see **Figure 1**). In fact, no participant ranked Help-Seeking/Resourcefulness as #1 on their list. Conversely, competencies such as Problem Solving/Abstraction and Growth Mindset were generally ranked

higher on individual particpant's lists (median = 2 for both) but had lower overall rankings due to not showing up on more participants' lists.

In consideration of the individual experts' differences in ranking, findings in this study provide a platform for lower-ranked competencies to burgeon in engineering education research and practice. For instance, the lowest three rankings in **Appendix A** (networking skills, empathy, and open-mindedness) do not imply a lack of importance but rather general unfamiliarity with the term. All competencies on the final ranked list were listed in at least two individual experts' lists of the top ten most important competencies. This finding suggests an opportunity for engineering education faculty, staff, and administrators to expand our shared understanding and language around what it means to support engineering student thriving. This shared language and understanding can help engineering faculty, staff, and administrators more easily align themselves in ways that are consistent in enhancing students' positive impressions of the institution.

Conclusions (with Limitations & Future Work)

In the aggregate, these findings provide an enhanced understanding of which key internal thriving competencies engineering faculty, staff, and administrators could address when creating environments conducive to thriving. These findings can inform engineering faculty, staff, and administrators' interactions with students when teaching, supporting, advising, mentoring, and/or working directly with undergraduate engineering students. This study extends prior research by simultaneously 1) highlighting the multidimensional view of engineering student thriving and 2) providing a concise shortlist of the most important internal thriving competencies that offer practical applications in future research. Future research can target the competencies with the lowest overall rankings, as these competencies were identified as highly important but generally unfamiliar terms among the engineering education community.

We also recommend future research on engineering student thriving to balance including multidimensional perspectives of engineering students with enough concision for practically feasible studies. For example, it is crucial to expand beyond studying just cognitive factors to incorporate intrapersonal, social, and behavioral competencies, as well as cultural and societal influences over time. However, developing a survey measuring all 147 factors of engineering thriving identified in prior work [2] with any evidence of validity and reliability will not be practically feasible. Thus, the concise list of ten most important competencies found in this study provides feasible starting points for researchers and practitioners to consider when creating environments and relationships conducive to engineering student thriving. This paper takes the first step at finding a balance between a concise and multidimensional view of engineering student thriving, which is crucial to consider in future work in research or designing programs and curricula that will support student thriving.

As with all studies, this research is comprised of limitations that can inform additional future work. First, findings from this study (which focuses on thriving for engineering students) do not include perspectives from the undergraduate engineering student population. Thus, future research will examine and compare these findings with rankings from actual engineering students' perspectives. Second, data in this study were collected prior to the COVID-19 pandemic, meaning the findings may not account for the consequences and lasting changes the pandemic caused (such as remote learning), which may affect

rankings. Finally, with larger sample sizes, it would be interesting to explore if and what statistical differences exist between the rankings of research faculty, teaching faculty, staff, and administrators. Furthermore, the critical competencies may be affected by the type of institution, e.g., Research 1, primarily undergraduate, or Community College, where the expert resides.

Ultimately, established members of the engineering education community have the responsibility to provide conditions that promote student thriving. The implication of these conditions has the potential to foster a positive impact on engineering students while obtaining their degrees as well as beyond graduation and into the workforce. The significance of creating these conditions has a substantial impact on society at large as these students will engage in an engineering workforce where their work directly influences the thriving of society at large.

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Appendix A

All Ranked Internal Thriving Competencies as Reported by Experts

Competency	Overall Score	Overall Rank
Communication/ Listening Skills	104	1=
Help-Seeking/ Resourcefulness	104	1=
Teamwork	97	3
Time Management	96	4
Resilience	95	5
Self-Awareness/ Sense of Self	94	6
Self-Regulation/ Discipline	82	7
Analytical and Critical Thinking	78	8
Problem Solving/ Abstraction	71	9
Growth Mindset	68	10
Learning/ Self-Learning/ Lifelong Learning	60	11
Curiosity	42	12
Motivation	39	13
Knowledge- Technical and Non-Technical	37	14=
Comfort with Uncertainty/ Complexity/ Ambiguity	37	14=
Adaptable	30	16
Social Skills	29	17
Understanding Global/ Environmental/ Systems Context	28	18=
Mindfulness/ Presence	28	18=
Interest	28	18=
Respect for People from Different Backgrounds	27	21
Positivity/ Gratitude	26	22
Meaning/ Purpose/ Holistic Intelligence	23	23=
Self-Care/ Stress Management	23	23=
Study Skills	21	24=
Goal Setting/ Orientation	21	24=
Reflection	21	24=
Strong Work Ethic	20	25=
Confidence	20	25=
Self-Respect	19	30
Sense of Empowerment	17	31
Help-Giving/ Caring/ Serving Others	16	32=
Creativity	16	32=
Responsibility	15	34
Metacognition	12	35
Integrity	11	36
Information Literacy	10	37=
Tinkering	10	37=
Emotional Intelligence	10	37=
Process Oriented	8	38=
Synthesis	8	38=
Integrative Learning	8	38=
Perspective Taking	8	38=

Conflict Resolution	8	38=
Achieving Goals/ Taking Action	6	39=
Navigating a rich Array of Educational Opportunities	6	39=
Emotional Competence and Control	6	39=
Professional Skills	6	39=
Inclusivity	6	39=
Personable/ Approachable	6	39=
Design Thinking	5	51
Visualization	4	52=
Open Mindedness	4	52=
Empathy	4	52=
Networking Skills	3	55