WIP: Developing an Instrument to Measure Adaptability among Engineering Students

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***Abstract*— This work-in-progress research paper presents the development and initial validation of an instrument to measure adaptability among engineering students. Adaptability is defined as responding quickly and flexibly to changing conditions and situations. Grounded in adaptability literature and theory, and informed by ongoing research, the instrument includes two scales corresponding to adaptability behaviors and mindsets. The online instrument will be piloted with undergraduate engineering students nationwide in the summer and fall of 2023. Exploratory factor analysis, confirmatory factor analysis, and multiple-item response analysis are planned to establish evidence of structural validity. Evidence of internal consistency reliability and stability reliability will also be collected. Findings using the instrument have the potential to influence university and industry stakeholders, engineering students, and researchers interested in studying engineering adaptability, which may, in turn, lead to better preparation and retention of engineers for the workforce.**

Keywords*— *engineers, adaptability, mindsets, behaviors, instrument development

I. Introduction

Rapid technological, economic, and global change has drastically altered how engineers today work and collaborate [1, 2]. Engineers must now adapt to continually changing job demands and solve increasingly complex and ambiguous problems requiring creative and interdisciplinary solutions [3]. Adaptability can be defined as responding quickly and flexibly to changing situations and conditions. Calls for greater emphasis on adaptability in engineering education date back at least three decades [4] and have come from industry, national organizations, and professional societies in various engineering fields [5-11], as well as from engineers themselves [12]. These calls focus on the anticipated benefits of having greater adaptability in the engineering workforce, including increases in its size, productivity, and national competitiveness [3]. However, adaptability within the engineering context is rarely defined, and what is meant by the term is not well understood. Engineering lacks a shared language and best practices to teach and assess adaptability [3]. This may partly explain extant research which shows that both early and late career engineers struggle with adapting to the job [13-15].

This work-in-progress research paper describes the initial design and development of the Engineering Adaptability Survey (E-ADAPTS) to measure engineers' adaptability attitudes and behaviors. Part of a larger National Science Foundation-funded project to investigate engineering adaptability, the instrument represents an important step towards better defining, measuring, and teaching adaptability as a key competency for engineering graduates. The instrument is intended for use by engineering educators, to assess the adaptability of engineering students and the strategies that best support its development; engineering students, as a tool for self-assessment; and other researchers, for adaptability-related studies, such as how adaptability demands differ across engineering contexts and how adaptability correlates with engineering outcomes. Ultimately, the goal of the instrument is to positively influence the preparation of students for the engineering workforce and the alignment of engineering education with professional practice. This paper provides an overview of the literature, theory, and research informing the instrument, then describes the process of instrument development and validation, including progress to date and future work.

II. Literature Review

Studies of adaptability have been conducted in such varied fields as psychology, leadership, human resource management, education, personality, and aging since the late twentieth century [16]. However, although both the general body of adaptability literature and interest in cultivating adaptability in engineering students have grown, research exploring what adaptability means in the engineering context remains limited, barring a few exceptions [17, 18]. Further examination of the attitudes and behaviors that make up engineering adaptability is needed if trainings and interventions to increase engineering students' adaptability are to be effective.

Adaptability is usually operationalized in the literature in terms of either individuals (e.g., employees), groups (e.g., teams, communities), or systems (e.g., organizations, infrastructure) [19, 20]. While each type of adaptability, the current study focuses on individual adaptability, specifically, the personal ability of engineering students to respond to change. Researchers have referred to individual adaptability by many names, among them, adaptive performance, adaptive expertise, adaptive transfer, and flexibility e.g., [21]-[23]. Regardless of terminology, adaptability is usually presented as multifaceted, spanning cognitive, affective, motivational, and behavioral domains [21]. For example, Allworth and Hesketh [22] defined adaptive performance as demonstrating the ability to cope with change and transfer learning from one task to another as job demands vary, emphasizing both a cognitive component related to problem solving and an affective component related to emotional regulation. More generally, Ployhart and Bliese [23] defined adaptability as the "ability, skill, disposition, and

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willingness and/or motivation to change or fit different tasks, social environments, or environmental features" (p. 13).

Thus, the literature supports that an adaptable engineer is one who, in addition to having the requisite skills, recognizes the need to adapt, wants to adapt, and feels confident and empowered in their ability to adapt. This view of adaptability aligns with Yeager and Dweck's [24] definition of mindsets as the attitudes, beliefs, and/or ideas that inform an individual's response to and interpretation of a situation and behavior as the individual's response to the situation itself. The current study focuses on the instrumentation of engineering students' self-reported adaptability mindsets and behaviors.

III. Theoretical Frameworks

Career Construction Theory and Individual Adaptability Theory are the two most cited theoretical frameworks in adaptability literature [16]. Together, they served as the foundation for the development of an instrument to measure the adaptability-related mindsets of engineering students.

Career Construction Theory was developed by Porfeli and Savickas [25]. It characterizes career adaptability as the combination of four mindsets: concern about one's career future, control over one's career future, curiosity about one's possible future career selves and scenarios, and confidence in the ability to pursue one's career aspirations. Notably, the theory is situated in a future-oriented career context, with emphasis on "the unfamiliar, complex, and ill-defined problems presented by developmental vocational tasks, occupational transitions, and work traumas" (p. 662) [25]. Psychological capital is a similar construct that can be used to characterize adaptability more generally. Its dimensions include (1) concern about (i.e., investment in) achieving a challenging task, (2) feeling in-control of one's ability to achieve the task, (3) curiosity about ways to persevere in achieving the task when confronted with problems, and (4) confidence in one's ability to achieve the task [26]. Together, career adaptability and psychological capital provide insight into the mindsets that motivate individuals to take particular actions, in this case, being adaptable.

Individual Adaptability Theory offers one of the more comprehensive definitions of workplace adaptability that includes both cognitive and affective aspects. It adopts Pulakos et al.'s [27] conceptualization of adaptive performance as a set of eight behaviors, which include (1) handling emergencies or crises, (2) handling stress, (3) solving problems creatively, (4) dealing with uncertain or unpredictable work situations, (5) learning new knowledge and skills, (6) demonstrating interpersonal adaptability, (7) demonstrating cultural adaptability, and (8) demonstrating physically oriented adaptability. Studies comparing the adaptability requirements of different occupations indicate that, of these behaviors, handling stress, solving problems creatively, dealing with uncertain or unpredictable work situations, learning new knowledge and skills, and demonstrating interpersonal adaptability are the most relevant to scientific and technical occupations [3, 28]. Adaptive performance is used in this study to define an initial set of behaviors that individuals demonstrate while being adaptable..

IV. Qualitative Findings

Findings from the larger National Science Foundation-funded project of which this study is part also informed instrument development. Semi-structured qualitative interviews with engineering managers and early career engineers were used to elicit critical incidents in which engineers needed to adapt while on the job. During the interviews, the managers and engineers identified various dimensions of adaptability critical to the work of engineers [29, 30]. Seven dimensions of adaptability emerged from the interview analysis. The first five corresponded to Pulakos et al.'s [27] dimensions of adaptive performance determined to be most closely associated with scientific and technical occupations [3, 28]. The sixth dimension, cultural adaptability, was included in Pulakos et al.'s [27] conceptualization of adaptive performance, but not among those identified as most related to technical professions. This finding was unsurprising, given the increasing importance of cultural adaptability as engineering teams become more global [1]. The last dimension, knowledge transfer, was not included in Pulakos et al.'s [27] description of adaptive performance. However, Ivancic and Hesketh [31] referred to adaptability as "using one's existing knowledge base to … generate a solution to a completely new problem" (p. 1968). Similarly, the National Academy of Engineering [6] described adaptability as learning new things quickly and applying knowledge to new problems and contexts. In sum, the input from managers and engineers corroborated those adaptability dimensions previously identified as critical to the engineering domain, with cultural adaptability and knowledge transfer also emerging as important. All seven dimensions were used in the operationalization of engineering students' adaptability behaviors.

V. Instrument Development

Instrument development was carried out by an engineering education research team comprised of one faculty member and one graduate student. The developed instrument, E-ADAPTS, contains two scales measuring engineering students' adaptability-related mindsets and behaviors. The instrument currently contains a total of 66 items. It is designed to be administered online, along with demographic questions, and to take 5-10 minutes to complete.

Specific items on the instrument were newly created and/or adapted from existing surveys of adaptability. A state-of-the-art review [32] of articles related to the quantitative measurement of individual-level adaptability was conducted. These articles were read and discussed by both members of the research team. Items considered potentially useful for measuring a particular adaptability mindset or behavior were identified for possible inclusion in the instrument. The surveys from twenty articles were considered. Surveys that were particularly salient to the instrument development process are called out in the descriptions of the two scales that follow.

A. Adaptability Mindsets

The Adaptability Mindsets scale measures engineering students' self-reported concern, control, confidence, and curiosity related to being adaptable. The initial version of the scale has 24 items. Respondents are asked to, "Rate your agreement with each statement in the context of your

experiences as an undergraduate engineering student," on a seven-point Likert scale, from 1 ("strongly disagree") to 7 ("strongly agree") [33]. Items for this scale were mainly influenced by [25], [34]. Definitions and sample items for each adaptability mindset are presented in Table 1.

TABLE I. ADAPTABILITY MINDSET SCALE

Mindset	Abridged Definition	Sample Item
Concern	Feeling invested in the need to adapt	I think keeping my knowledge and skills up to date is important.
Control	Feeling autonomous over decisions about whether and how to adapt	I feel empowered to solve problems when they present themselves.
Confidence	Feeling like one has the knoweldge, skills, and abilities to adapt	I am confident in my ability to navigate stressful events in my life.
Curiosity	Feeling interested in exploring different ways one could adapt	I like exploring my options before deciding how to respond in a situation.

B. Adaptability Behaviors

The Adaptability Behaviors scale measures engineering students' self-reported performance on the seven dimensions of adaptability behavior that emerged from the interviews with managers and early career engineers: (1) creative problem solving, (2) interpersonal adaptability, (3) cultural adaptability, (4) ability to handle stress, (5) ability to deal with uncertain and unpredictable situations, (6) continuous learning, and (7) knowledge transfer. The initial version of the scale contains 42 items. Respondents are asked to, "Think about your past experiences as an engineering student and answer how true each of the following statements are to you." Response options are arrayed on a seven-point Likert scale which includes response options from 1 ("never or rarely true of me") to 7 ("always or almost always true of me") [33]. Items for this scale were mainly influenced by [21], [23], [27]. Definitions and sample items for each adaptability behavior are presented in Table 2.

TABLE II. ADAPTABILITY BEHAVIOR SCALE

Mindset	Abridged Definition	Sample Item
Creative problem solving	Employing unique methods to generate new and innovative ideas	I don't hesitate to go against established ideas to find innovative solutions.
Interpersonal adaptability	Being flexible and open-minded when interacing with and receiving feedback from others	I adjust how I do things if someone points out a better solution.
Cultural adaptability	Being receptive to the customs, needs, and values of different groups, organizations and cultures	I have an easy time adapting to other people's needs and requirements.
Ability to handle stress	Remaining composed and cool when faced with difficult circumstances, demanding workloads, or new situations	I keep calm in situations where I need to make many decisions.
Ability to deal with uncertain and unpredictable situations	Taking effective action when necessary without having to know the total picture or have all the facts at hand	Reorganizing my day to adapt to new circumstances is not a challenge for me.
Continuous learning	Learning new methods or approaches, to improve one's performance or deficiencies	I regularly seek out opportunities to acquire new skills.
Knowledge transfer	Applying existing knowledge and skills to new problems or contexts	I often think about how I can apply what I've learned to different areas of my life.

VI. INSTRUMENT VALIDATION

The current study adopts Messick's [35] unified view of validity wherein researchers gather evidence of multiple aspects of construct validity to support the interpretation of data from the instrument for a particular population. Evidence of the instrument's construct validity is being collected in three phases. To date, the first phase has been conducted. Experts in adaptability theory, psychometric measurement, engineering education, and research on engineering practice reviewed the instrument to provide evidence of content validity [36]. These experts gave feedback on item relevance, appropriateness, and clarity. Focus groups of undergraduate engineering students were also collected as evidence of face validity. Each focus group was asked to identify items they found unclear or confusing, and these items were revised using the students' suggested modifications [36].

The second phase will establish preliminary evidence of structural validity. A pilot deployment is planned for summer 2023. The instrument will be administered to the undergraduate engineering student population at a large public, doctoral-granting university in the western United States. Exploratory factor analysis [36] will be conducted on the responses to reduce the number of items on the survey and determine an initial factor structure for both the adaptability mindset and adaptability behavior measures. Items describing the same mindsets are expected to load together on the factor structure for mindsets, while items describing the same behaviors are expected to load together on the factor structure for behaviors.

The third phase will seek to collect further evidence of the instrument's structural validity. The instrument will be modified based on the results of the exploratory factor analysis and then redeployed to the undergraduate engineering student populations at three additional large public, doctoral-granting universities in the United States during the fall 2023 semester. Confirmatory factor analysis will be run to verify the factor structures obtained in the exploratory factor analysis [36]. Following this step will be multiple-item response analysis, to ensure that there are no ceiling effects and/or poor fitting items, both which make the detection of pre-post changes using the instrument easier [36]. Lastly, evidence of internal consistency reliability and stability reliability will be conducted with a group of undergraduate engineering students who will be asked to complete the survey again one week later. The internal consistency reliability of each scale will be calculated using Cronbach's alpha [37]. In addition, correlations between the pre- and post-scores will be calculated to confirm that participant scores are invariant to time in the absence of an intervention [36]. Complete findings from the instrument development and validation process will be shared in a future journal article.

VII. Future Work

Two threads of future work are currently underway. First, a set of online modules to increase engineering students' adaptability is being designed. Research shows that statistically significant increases in adaptability are possible even after relatively short course- or training-based interventions. The validated instrument will be used to test the effectiveness of these modules via a delayed-treatment randomized control trial [38]. Second, recognizing the limitations of self-report instruments, situational judgment tests and observational protocols are also being developed to more objectively evaluate students' adaptability – situational judgment tests assess an individual's knowledge about what skills to use and how to use them when confronted with a particular scenario [39], while observation protocols are used to externally assess individual behavior or performance [40]. These data collection tools will be designed, developed, and disseminated in conjunction with the self-report instrument.

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