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Development of the Fit of Personal Interests and Perceptions of Engineering Survey (F-PIPES) Instrument (Fundamental)

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Kayla is a doctoral student in the School of Engineering Education at Purdue University. Her research interest includes the influence of informal engineering learning experiences on diverse students' attitudes, beliefs, and perceptions of engineering, and the relationship between students' interests and the practices and cultures of engineering. Her current work at the FACE lab is on teaching strategies for K-12 STEM educators integrating engineering design and the development of engineering skills of K-12 learners.

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Dr. Su's research has been published in high-impact psychological and management journals such as Psychological Bulletin, Perspectives on Psychological Sciences, Journal of Personality and Social Psychology, Journal of Applied Psychology, and Journal of Management. Her work has been cited over 3,000 times according to Google Scholar as of October 2020 and has been featured in major media outlets including Time and The New York Times. She currently serves as an Associate Editor for Psychological Bulletin. Outside of her academic appointment, Dr. Su is actively involved in the dissemination and application of research to make a broader impact. She has served as a research consultant on the ongoing development of the Occupational Information Network (O*NET) for the U.S. Department of Labor, on the assessment of adult non-cognitive skills, interests, and well-being for the Organisation for Economic

Cooperation and Development (OECD), and on assessments of workforce readiness for Educational Testing Service (ETS). She has concluded eight grant-funded research projects to date in the role of PI or Co-PI totaling $1.2 million.

Development of the Fit of Personal Interests and Perceptions of Engineering Survey (F-PIPES) Instrument (Fundamental Research)

Introduction

There has been a significant push in the United States during the past decade to provide pre-college students experiences to engage in engineering learning activities. Motivations behind providing these experiences include developing students' technological literacy and 21st Century skills (Brophy, Klein, Portsmore, & Rogers, 2008; Miaoulis, 2014; National Research Council (NRC), 2009), attracting more people into the profession (National Academy of Engineering, 2008), and diversifying the engineering workforce (Black, 1994; Wulf, 2006), to name a few. However, even with the significant resources committed (Gibbin & Davis, 2002) to this work, there has been little shift in recruiting more students from underrepresented groups into engineering. Certainly, there are myriad factors at play with regard to engaging more students in an engineering education, and it is likely impossible to fully understand the interplay between and significance of all these factors. Many of the earlier studies in this domain were focused on understanding students' conceptions of engineers and the work of engineers and how they improved with various interventions (Hynes et al., 2017). This was important in that many students had never been exposed to engineering and only had the reference of the engineer that drives a train (Knight & Cunningham, 2004b). However, with the recent increased attention on introducing students to engineering, the focus of such interventions and studies has shifted to constructs that researchers believe will be better predictors of students choosing to pursue engineering as a college major and/or career (Hynes et al., 2017). Those include identity, perceptions of engineering, attitudes and beliefs toward engineering, self-efficacy in engineering, and interest in engineering. One factor that has been consistently cited among those conducting research and evaluation of such programs is students' perceptions, attitudes, and beliefs toward engineering (Hynes et al., 2017). There have been mixed results with respect to the extent to which in-school and out-of-school engineering programs are able to increase students' perceptions, attitudes, or beliefs about engineering.

hile there has been much work, there is little evidence to support that this increase in interest is leading to more students pursuing engineering. Maybe the increased interest is still not as strong as interests in other domains, or maybe the field is not measuring the appropriate kind of interest. Further confounding such measure of interests in engineering is the expectation that students have a clear understanding of what engineering is. When a student responds to an item asking them the extent to which they "like engineering," they are really responding to how much they like what they perceive engineering to be as a discipline, which could be quite limited. These types of issues with typical interest items used in pre-college engineering survey instruments is the motivation for the development of the engineering perceptual fit instrument presented here. In this paper, we will first discuss in more detail the background of what has been done with respect to research and evaluation of pre-college engineering interventions focused on addressing underrepresented groups (girls and certain minority groups). Then we will introduce the theoretical framework guiding the development of the Fit of Personal Interests and Perceptions of Engineering Survey (F-PIPES) instrument. Finally, we share the development of the survey and initial pilot results.

Background

Formal and concerted efforts to introduce students to engineering prior to college are still relatively new with some estimating the early 1990s as a starting point (Miaoulis, 2014; National Research Council (NRC), 2009) followed by a much more formal push in the early 2000s (Hynes et al., 2017) as states began introducing standards and frameworks for introducing engineering in the pre-college classroom (Carr, Bennett IV, & Strobel, 2012; Sneider & Purzer, 2014). Much of the early pre-college engineering education outreach focused on raising the awareness of what engineering was and what engineers do. Young students often held perceptions that engineering was primarily about building and fixing things such as cars, buildings, and heavy machinery (Knight & Cunningham, 2004a; Thompson & Lyons, 2008). The National Academy of Engineering (NAE) (2008) commissioned a report to change the conversation of what engineering was and position it as a career that was about helping people and the world . Common to the effort presented in this paper and other efforts to introduce students to engineering was the desire to diversify the engineering profession. The underrepresentation of women and certain minority groups was seen as a distinct problem in fulfilling the growing needs of the engineering profession. In 1995 the Women, Minorities, and Persons with Disabilities in Science and Engineering report (National Science Foundation & National Center for Science and Engineering Statistics, 2017) began recording and reporting statistics with respect to the numbers of women, minorities, and people with disabilities entering STEM professions. The report shows that women have consistently represented about 20% of engineering graduates, in that time period, while African American's, Hispanic/Latinx, and Native American's are severely underrepresented given their representation in the nation more broadly. Investments in pre-college engineering education outreach and diversity efforts increased substantially from federal agencies (Committee on Equal Opportunities in Science and Engineering (CEOSE), 2017), universities , and the private sector (Gibbin & Davis, 2002). A conservative estimate compiled from the NSF's budget reporting and the report on raising public awareness put investments in the billions of dollars (Committee on Equal Opportunities in Science and Engineering (CEOSE), 2017; Gibbin & Davis, 2002). While not all this money was invested primarily in pre-college engineering education initiatives, the investment has been significant. However, even with these investments, there has not been any significant increase in the percentage of women or people from certain minority groups participating in engineering.

To understand the types of assessment approaches being used to measure students' affective views—attitudes, beliefs, interests, perceptions, self-efficacy, and identity-with respect to engineering , we built upon the systematic literature review by Hynes et al. (2017). In the review, the authors explored peer-reviewed journal publications on P-12 engineering education from 2000-2015 across five large periodical databases (PsycInfo, EBSCO Full text/ERIC, Scopus, Professional Development Collection, EBSCO Education source. Since we are interested in the measures of students' affective views with respect to engineering focused interventions, we modified the search criteria to include terms such as *interests, attitudes, self-efficacy, identity, motivation, and aspirations.* These affective views were chosen as areas of concentration because they are the most commonly used as measures that, if increased, would predict a higher likelihood of students pursuing engineering. With the additional search terms for students' affective views, we repeated search across the five periodical databases and restricted for peer-review journal publications. The resulting publications of each search was consolidated using

Mendeley citation manager where duplicates were removed. Following the removal of duplicates, we reviewed the article's title and abstracts against the following research context inclusion criteria: (1) participants in P-12 engaged in a STEM intervention with some focus on engineering, and (2) the measured affective view(s) focused on the views of the student as it relates to engineering not the teacher, facilitator, or educator. Lastly, we scanned the remaining articles'' full-text against the research context inclusion criteria. This process resulted in seventy (70) research papers focusing on pre-college students engaging in engineering focused interventions.

The search process resulted in a large variety of engineering initiatives or interventions and assessment approaches. In addition, this set of publications included a mix of initiatives or interventions with a focus on promoting engineering career pathways among girls (N=14) and minority populations (N=9). For example, 64% of the initiatives dedicated to promoting engineering as a career pathway for girls through exposure to role models or mentors in STEM-related disciplines (Ferraria, 2002; Farland-Smith, 2012; Everage, Feldhaus, Talber-Hatch, & Fernandez, 2014; Sheun, Elia, Xu, Chen, Jiang, Litkowski, Bonhivert, Hsu-Kim, & Schwartz-Bloom, 2011; Cooper & Heaverlo, 2013; Hughes, Nzekwe, & Molyneaux, 2013; Lui, Lou, & Shih, 2014; Nadelson & Callahan, 2011; Pinkard, Erete, Martin, & Mckinney de Royston, 2017). Other interventions included hands-on learning activities to engage participants with a variety of engineering-related concepts through game design, robotics, space systems, sustainability, mechanical systems, electro-optics, and more to influence students' attitudes, interests, perceptions, and self-efficacy (Clark & Sheridan, 2011; Leonard, Buss, Gamboa, Mitchell, Fashola, Hubert, & Almughyirah, 2016; Brown, Concannon, Marx, Donaldson, & Black, 2016; Mohr-Schroeder, Miller, Little, Schooler, Jackson, Walcott, Speler, Craig Schroeder, 2014; Hylton & Otoupal, 2009; Gero & Zach, 2014). In addition to variations in the initiatves or interventions, the measures of students' affective views varied across papers. Table 1 shows the distribution of affective constructs being measured within the literature.

Table 1: Distribution of Pre-College Engineering Education Research Papers and Associated Affective Constructs

Affective Construct	Number of Papers
Attitudes	19
Beliefs	4
Interests	23
Perception	20
Self-efficacy	21
Identity	17

Futhermore, these papers represent a variety of tools for assessing (e.g., interviews, observations, surveys, and artifact analysis) students' attitudes, beliefs, interests, perceptions, self-efficacy, and identity. For example, there are multiple survey tools being used. Some papers used modified version of the Motivated Strategies for Learning Questionnaire developed by Pintrich, Smith, Garcia, & McKeachie (1991) to evaluate self-efficacy (Lawanto et al., 2013; Nugent et al., 2010) or modified version of the Test of Science Related Attitudes (TORSA) (Fraser, 1981; Clewett &

Tran, 2003; Elam et al., 2012; Naizer et al., 2014). Others used Engineering Identity Development Scale to evaluate engineering identity (Capobianco et al., 2015; Capobianco et al., 2017); items adapted from National Center for Educational Statistics Longitudinal Study (NELS) and the American Women in Engineering to evaluate STEM career interests (Christensen et al., 2013; Notle & Harris, 2010); MUSIC Model of Academic Motivation (Jones, 2012; Jones et al., 2015); or modified version of Engineering and Technology Instrument (Ruff, 1993; Mativo et al., 2013). In addition to survey tools, most of the literature used a customized combination of observations, field notes, interviews, survey tools, and artifacts to evaluate affective constructs.

Improving students' interests in engineering was an aim for 23 of these studies, but there was not a validated survey instrument grounded in interest theory used as a basis for measuring interests change. The research papers use modified questions from the Test of Science Related Attitudes (TOSRA) (Fraser, 1978) like, "I would like to be an engineer when I leave school" (Elam, Donham, & Solomon, 2012) or "How interested are you in a job like these someday?" (Aschbacher & Tsai, 2014). As previously mentioned, asking a student this sort of question assumes that their conception of engineering and what engineers do is at least some accurate approximation of the profession. We posit that this might not be a valid assumption and motivates our development of a survey instrument, grounded in the psychology of interests, that considers the students' perception of what engineering is and what engineers do.

Theoretical Framework

As pre-college engineering education classroom and outreach interventions seek to measure students' likelihood to pursue an engineering education or career, it is important to be clear on precisely what the instruments they are using are measuring. There is a strong theoretical case from literature in psychology that ties a person's interest in a particular domain to the likelihood that they will persist in that domain and pursue it within their long-term goals (Atkinson, Wickens, & Glaser, 1971; Bolles & Zeigler, 1967; Deci, 1992; Renninger, Hidi, & Krapp, 1992). Strong's (1943) seminal work showed that one's preferences for a particular work environment were highly related to their success in that environment. Similar insights have been seen with respect to persistence and success in learning contexts where higher levels of both personal and situational interest lead to increased student engagement, learning, and achievement (Eccles, Wigfield, & Schiefele, 1998; Hidi, 1990; Linnenbrink & Pintrich, 2002; Pintrich, 2003; Schiefele, 2012; Schiefele, Krapp, & Winteler, 1992).

However, the literature also makes an important distinction about a person's interests. A person's interests can be categorized as either situational or personal (Krapp, Hidi, & Renninger, 1992). Situational interests are related to the interestingness of the social or non-social environment that encourages one to interact with people or objects. For example, attending a party or event may evoke interest within an individual if they like the people they are interacting with or the activities in which they are engaging. Personal interests relate to the characteristics of a person that influence their choice to engage and interact within the social or nonsocial environment. For example, if someone likes caring for people, they may pursue a career as a nurse, doctor, social worker, etc. It is important to consider this distinction of interests in designing an instrument to measure a student's interest in engineering so as to be clear whether it is measuring students' situational interest in engineering (e.g., how fun it may have been to engage in a particular engineering activity) or their personal interest in engineering (e.g., how well does engineering as a discipline align with personal interests, goals, and motivations). Situational interest predicts engagement and learning within the situation that arouses interest, whereas personal interests, due to their relative stability, are stronger predictors of longer-term outcomes including academic achievement, persistence, choice of college major, career choice, job performance, and career success (Renninger et al., 1992).

One area of interest for the field of engineering education relates to engaging students in engineering activities with the aim of promoting engineering as a potential career for the students. Numerous theories and models of career development build upon Bandura's (1986) model of triadic reciprocality relating personal, environment, and behavior factors (Lent, Brown, Hackett, 1994; Pajares & Urdan, 2005). In this relationship, personal factors (e.g., personality traits or personal interests) interact with environmental contexts (e.g., learning experiences or interventions) that can lead to specific behaviors or actions (preference or choice of a career). Lent, Brown, and Hackett (1994) proposed the social cognitive career theory (SCCT) where personal interests help shape an individual's intentions, goals, and engagement in particular career pathways that then leads to persistence in the chosen pathway. They proposed that positive outcome expectations and increased self-efficacy with respect to persistence in a career field are key to the development of personal interests in that field. Similarly, Eccles and colleagues (1983; also see Eccles, 2009) proposed the expectancy-value theory (EVT) that links students' expectation of success and perceived value in academic activities (including intrinsic interest in those activities) to their academic/career choice and achievement. The experience of engaging and succeeding in an academic/career field further influence students' future outcome expectation and the development of their interest in the field. Applying these theoretical models and Bandura's notion of triadic reciprocality, an intervention that highlights how students' skills and abilities can relate to engineering can both improve a students' self-efficacy with respect to engineering as well as their outcome expectations. For example, a series of intervention studies based on the EVT have been shown to successfully increase student interest in school subjects such as math and science by highlighting the personal relevance of the subjects for students and helping students connect the subjects to their own lives (e.g., Harackiewicz, Rozek, Hulleman, & Hyde, 2012; Hulleman, Godes, Hendricks, & Harackiewicz, 2010; Hulleman & Harackiewicz, 2009).

Further, in the Theory of Vocational Personalities and Work Environments, Holland (1997) highlighted the importance of the congruence, or fit, between an individuals' personal interests and characteristics of a particular vocation and the association between interest congruence/fit and positive outcomes in that profession. In other words, it is not only how high or low a person's interest in one area is that matters, but also the pattern, of profile, of interests across a combinations of areas that is predictive of academic/career choice and persistence within a chosen field. Specifically, Holland's theory states that personal interests can be characterized with six distinct dimensions (see Table 1). Each person's personal interests profile would be comprised of some mix of these six dimensions. For example, someone may have high personal interests in the social and artistic dimensions, a moderate interest in realistic, and low interest in investigative, enterprising, and conventional. A career that provides a good fit for the person, according to the theory, would be comprised of a similar profile, offering many opportunities to fulfill one's social and artistic interests and less in other areas. Meta-analyses have shown that interest congruence/fit is substantially more predictive than the level of person interests in any one dimension (Nye, Su, Rounds, & Drasgow, 2012, 2017). For example, Nye et al. (2012) quantitatively summarized interest research over the last 60 years and found that, on average, the level of personal interests is positively related to academic performance and persistence in school ($r = .21$ and $.25$, respectively) but interest congruence/fit has significantly stronger correlations with these outcomes ($r = .30$ and $.34$, respectively).

When applied in practice, interest fit can be assessed in three ways (Edwards, Cable, Williamson, Lambert, & Shipp, 2006). A student can take a personal interest inventory and the results are then matched with the profiles of various careers to find the best fit. This approach of assessing fit is referred to as the "atomistic" approach (Edwards et al., 2006), as personal interests and characteristics of various career fields are examined as separate entities. One of the most widely administered personal interest inventories, Holland's Self-Directed Search (Holland, Fritzsche, & Powell, 1994), has been translated into 25 different languages and has been used by over 22 million people worldwide. Another highly regarded personal interest measure, Strong Interest Inventory (Donnay, Morris, Schaubhut, & Thompson, 2005), is the most widely used in guiding college students' career choice in the U.S. In the non-commercial domain, under the sponsorship of the U.S. Department of Labor, the National Center for O*NET Development provides the O*NET Interest Profiler (Rounds, Su, Lewis, & Rivkin, 2010) that is available online for free to assist tens of thousands of students and working adults in making school-to-work or career transitions. All of these personal interest measures assess the six interest dimensions proposed by Holland (1997), which are then compared to the characteristics of various occupations in the same six areas. This sort of matching, in theory, aligns a student's personal interests to a career, whereas, a question asking whether a student likes engineering is more likely measuring the student's situational interest related to the engineering activity in which they recently participated.

Despite the strength of the atomistic approach to assessing interest fit, it has a drawback: the characteristics of occupations are typically derived normatively. For example, the characteristics of engineering are determined either by expert ratings or using large samples of job incumbents (practicing engineers). However, engineering is a highly diverse field with myriad opportunities that may require very different skills and abilities (Figueiredo, 2008). The database of career profiles (onetonline.org) is generated by asking practicing engineers about their roles and responsibilities and observing what they do. In aggregate, this reduces what engineers do to a more stereotypical profile, which in general is highly investigative, realistic, and moderately conventional. This type of profile leaves out existing and emerging careers in engineering that may appeal to more social, artistic, and enterprising personality dimensions. Another issue with the stereotypical profile of engineering careers is that it is primarily built upon the profiles of the dominant culture within engineering—white males. This overrepresentation is problematic in that it limits the opportunity for diverse perspectives to contribute to the design of new products and systems (Wulf, 2006) that are intended to apply to broad contexts and demographics of people.

A second approach to assessing fit is by directly asking individuals the extent to which they think a particular career pathway (e.g., engineering) fit with their personal interest. This approach is referred to as the “molar” approach to assessing fit (Edwards et al., 2006), as the perception of fit is captured holistically in one question. However, this approach also has its drawback, because the perception of fit is highly subjective and is likely influenced by many factors. This approach is most similar to measuring situational interest, which is relatively unstable over time and across different contexts. Edwards et al. (2006) showed that subjective perceptions of fit were only modestly related to objective forms of fit.

Alternatively, we propose using the third approach to assessing fit, which is to compare students’ personal interests with their own perceptions of particular career fields. This approach is referred to as the “molecular” approach to assessing fit (Edwards et al., 2006). By determining the characteristics of an occupation (e.g., engineering) using a person’s own evaluation, it captures the idiosyncratic nature of each person’s experience and perception of the occupation and avoids representing the occupation in a stereotypical profile. In the meanwhile, by assessing the degree of fit between students’ personal interests and their perceptions of engineering, it mitigates the extent to which the instrument is measuring a student’s fleeting situational interest in a short-term engineering activity. Given the goal of trying to have engineering appeal to new and different groups of students, we propose first understanding how students perceive engineering and helping them modify their perception of engineering to one that is both a better match to the profession and the student’ personal interests profile.

Table 2: RIASEC personality dimensions and descriptions

Personality dimension	Description
Realistic	A preference for activities that entail the explicit, ordered, or systematic manipulation of objects, tools, machines, and animals and to an aversion to educational or therapeutic activities. These behavioral tendencies lead in turn to the acquisition of manual, mechanical, agricultural, electrical, and technical competencies and to a deficit in social and educational competencies. p. 21 Holland (1997, p. 21)
Investigative	A preference for activities that entail the observational, symbolic, systematic, and creative investigation of physical, biological, and cultural phenomena (in order to understand and control such phenomena) and to an aversion to persuasive, social, and repetitive activities. These behavioral tendencies lead in turn to an acquisition of scientific and mathematical competencies and to a deficit in persuasive competencies. p. 22 (Holland, 1997, p. 21)
Artistic	A preference for ambiguous, free, unsystematized activities that entail the manipulation of physical, verbal, or human materials to create art forms or products and to an aversion to explicit, systematic, and ordered activities. These behavioral tendencies lead in turn to an acquisition of artistic competencies (e.g., language, art, music, drama, writing) and to a deficit in clerical or business system competencies. p. 23 (Holland, 1997, p. 21)
Social	A preference for activities that entail the manipulation of others to inform, train, develop, cure, or enlighten and an aversion to explicit, ordered, systematic activities involving materials, tools, or machines. These behavioral tendencies lead in turn to an

	acquisition of human relations competencies (e.g., interpersonal and educational) and to a deficit in manual and technical competencies. p. 24 (Holland, 1997, p. 21)
Enterprising	A preference for activities that entail the manipulation of others to attain organizational goals or economic gain and an aversion to observational, symbolic, and systematic activities. These behavioral tendencies lead in turn to an acquisition of leadership, interpersonal, and persuasive competencies and to a deficit in scientific competencies. p. 25 (Holland, 1997, p. 21)
Conventional	A preference for activities that entail the explicit, ordered, systematic manipulation of data (e.g., keeping records, filing materials, reproducing materials, organizing business machines and data processing equipment to attain organizational or economic goals) and to an aversion to ambiguous, free, exploratory, or unsystematized activities. These behavioral tendencies lead in tum to an acquisition of clerical, computational, and business system competencies and to a deficit in artistic competencies. pp. 26-27 (Holland, 1997, p. 21)

Using the aforementioned "molecular" fit approach, we believe engineering educators will have an opportunity to develop and test engineering interventions that draw upon the six dimensions of interests in ways that maximize fit among their students or highlight certain aspects of engineering's epistemology. This sort of manipulation of engineering interventions may be seen as a sort of bait-and-switch deception where students see engineering as something particularly interesting to them, which may be met by a very different experience of engineering education in a traditional university engineering program. However, as previously mentioned, the diversity of people and perspectives in traditional university engineering programs is seen as lacking and problematic. We believe one way to begin to change the status quo is to have those entering the program continue to apply the pressure to change the system to meet their needs and desires. Given the broad work of engineers in practice, we do not believe that highlighting artistic aspects of engineering work is a dishonest representation of a future engineering position an individual may find themselves in.

Design & Method

The research team followed a method described by Clark and Watson (1995) for the scale development and validation along with additional validity evidence gathering as outlined by the AERA, APA, and NCME standards for educational testing (2014). Clark and Watson describe ensuring substantive validity to develop the initial scale items by conceptualizing the scale, reviewing the associated literature related to the construct(s) and context, and following best practices for formatting and writing the items. The additional validity evidence would be gathered by further ensuring the instrument was appropriate for the given context and purposes of the study. Once initial items are developed, they describe a series of psychometric analyses that will ensure structural validity of the scales as they relate to the constructs being measured. Results from the structural validity analyses will determine which items can be eliminated from the final scale. After addressing substantive and structural validity, we detail the findings in context of the engineering intervention.

Substantive validity: Item development for Fit of Personal Interests and Perceptions of Engineering Scale (F-PIPES)

Clark and Watson (1995) describe the conceptualization process as the development of a theoretical framework that is thoughtfully situated in both broader psychological constructs (e.g., interests) as well as those more narrow-band, context specific constructs (e.g., perceptions of engineering). The theoretical framework developed above lays out our proposed conceptualization for determining fit between a student's personal interests and their perceptions of engineering as a predictor for the pursuit of engineering as a career. From this theoretical frame, the research team adapted a validated and widely-used personal interest scale (Rounds, Ming, Cao, Song, & Lewis, 2016) to be used in conjunction with the perceptions of engineering scale similarly built upon Holland's six constructs for personal interests. Items for the scales were developed through an iterative, interdisciplinary process, which we describe below.

Personal interests. First, the Mini Interest Profiler (Mini-IP), a 30-item personal interest assessment from the Occupational Information Network (O*NET) (Rounds et al., 2016) was selected as the basis for constructing our measure of personal interests because of its brevity (30 compared to others with 60-180 items) and its suitability for the targeted age group of the current study (8-14 year olds) who have limited attention span compared to older children and adults. The O*NET Interest Profiler was developed under the sponsorship of the U.S. Department of Labor and is widely used by job seekers and students who are entering the workforce. Previous research has documented the satisfactory reliability and validity of the measure (Rounds et al., 2016). Our instrument adapted the 30 items from the Mini-IP such that each item is worded at the reading level of our target age group, with 5 items measuring each of the six dimensions from Holland's (1997) theory. Example items included "Build things with LEGO bricks" (Realistic), "Do a science experiment" (Investigative), "Draw pictures" (Artistic), "Help other students in your class" (Social), "Sell something that you made or at home" (Enterprising), and "Sort your things into boxes" (Conventional).

Perceptions of engineering. To ensure substantive validity in the development of the perceptions of engineering scale, we used a three-pronged approach that included building upon a prior interview study of students of the target age range (Hynes et al., 2016), expert review from both engineering and organizational psychology disciplines, and review of relevant literature to ensure the items were appropriate for the context and purposes of the study (AERA, APA, & NCEM, 2014). Initial items were created by the first two authors—one who has expertise in pre-college engineering education and another who has expertise with career theory and instrument development—and were mapped onto the six dimensions of Holland's career theory and the nature and epistemology of engineering. We developed eight original items for each of the six dimension that describe a range of activities that engineers may do in their jobs. These initial items drew upon vocabulary and conceptions of engineering used by students from a prior interview study of students' perceptions of engineering (Hynes et al., 2016) to ensure items were appropriate for the target populations. Those items were then presented to a team of experts with varying engineering and teaching backgrounds. After several iterations between that team and the first two authors, a set of 48 items comprised the instrument for assessing students' perceptions of engineering for piloting. Example items included "Fix broken things" (Realistic), "Use math to solve problems" (Investigative), "Draw, sketch, doodle or paint" (Artistic), "Make the world a better place" (Social), "Organize business agreements" (Enterprising), and "Write reports" (Conventional). We intended to select four items with the best psychometric property out of the eight original items for each dimension to construct the final instrument. The reason for this item reduction process is to keep the total scale length short (24 items) to be appropriate for young students' limited attention span while maintaining an acceptable level of reliability for each subscale.

Structural validity

Participants were recruited through a summer day program hosted at a large, public, Midwestern University. We invited 425 students aged 8 to 14 years old to enroll in this study all of whom qualified for free or price-reduced lunch. Among these students, 260 were admitted to the study after receiving both parental consent and student assent. The summer program was a total of twenty days. The students were split into ten groups. Five groups visited one set of five stations for the first ten days and then switched to five new stations for the final ten days. These stations included engaging students for forty-five minutes at a time in various sports (e.g., basketball, soccer, swimming, judo, etc.) and other more academic topics (e.g., art, videography, computer programming, engineering, etc.). For this intervention, we saw five groups of approximately 40 students every 45 minutes for the first ten days, and then five new groups for the final ten days. The students arrived at 8:00 a.m. each morning and were served both breakfast and lunch. The F-PIPES instrument was tested while the students participated in the engineering station using a paper and pencil format.

The students all completed a pre-intervention survey on the first day of the summer program. In the survey, they provided demographic information including gender, age, and race, and completed measures of their personal interests, perceptions of engineering, and interest in engineering. After the intervention (which is described below), all 260 participants completed measures of perceptions of engineering and interest in engineering for the second time, on the last day of the engineer station. After matching the pre- and post-intervention surveys and deleting four participants who had completely no variability across all their answers, the total sample was consisted of 209 participants, with a response rate of 80.4%. Among the participants, 90 (43.1%) identified as female, 109 (52.2%) identified as male, and 10 participants (4.8%) did not report their gender; 60 (28.7%) identified as White, 51 (24.4%) identified as African American/Black, 68 (32.5%) identified as Latinx, 13 (6.2%) identified themselves as Other, and 27 participants (12.9%) did not fully report their race and ethnicity information. The average age of all participants was 9.91 years old (SD = 1.57).

Personal interests. Participants' personal interests were measured with our adapted version of the O*NET Mini-IP (Rounds et al., 2016). Students were asked to indicate their level of interest for each activity described by an item, with a choice among "Dislike" (coded as 1), "Neither" (coded as 2), and "Like" (coded as 3). The reliabilities of the scales were acceptable in the current sample and were typical of this age group, with Cronbach's α coefficients ranging from .62 for Realistic, .69 for Enterprising, .72 for Artistic, .73 for Conventional, .75 for Investigative, to .87 for Social.

Perceptions of engineering. During the pre-intervention survey, students were asked to report their perceptions of engineering with all 48 original items that we developed by rating the extent to which they think engineers do each activity described by an item, with a choice among "Not much" (coded as 1), "Some of time" (coded as 2), and "A lot" (coded as 3). Based on students' responses, we calculated the inter-item correlations for the 48 items and selected four items for each subscale that demonstrated high average correlations with items within the same subscale and low average correlations with items on other subscales that were conceptually distinct. For example, the item "draw, sketch, doodle, or paint" was selected as one of the final four items to construct the Artistic subscale because it demonstrated substantial overlap with other items on the Artistic subscale (average $r = .45$) and was distinct from items on other subscales (average $r = .27$). Doing so helps ensure a high level of consistency for the four items with each perception dimension and a high level of distinctiveness among the six perception dimensions. As expected, subscales of the 24-item instrument presented satisfactory levels of reliability in the current sample that were typical of this age group. Cronbach's α coefficients in the pre-intervention survey ranged from .68 for Social and Realistic, .69 for Investigative and Conventional, .72 for Enterprising, to .75 for Artistic (see Table 3). Students took this instrument again after the intervention. Cronbach's α coefficients post-intervention ranged from .69 for Conventional, .73 for Realistic and Artistic, .75 for Enterprising and Social, to .77 for Investigative (see Table 3).

Further, we evaluated the structure of new Perceptions of Engineering scales using a bi-factor confirmatory factor analysis (CFA) model. In a bi-factor CFA model, each item is specified to load on the conceptually relevant subscale factor (e.g., item "draw, sketch, doodle, or paint" on the Artistic factor) as well as an orthogonal general perception factor that is hypothesized to influence all the items. As a result, covariance among the perception items is attributed to two sources: (1) a general perception factor representing the common variance shared by all the items; and (2) perception subscales representing unique variances corresponding to Holland's (1997) six dimensions. An example diagram of this bi-factor CFA model is depicted in Figure 1. This general factor needs to be parsed out when evaluating the structural validity of the six substantive scales because an acquiescence factor (response bias or general attitude) has been widely reported in psychological research with self-report measures (Paulhus & Vazire, 2007). Some respondents have a general tendency to endorse all the items highly across measurement scales, whereas others have a general tendency to provide lower ratings across the board. It is well documented that self-ratings of many psychological constructs reflect this general factor, including personality (e.g., Messick & Jackson, 1961), interests (e.g., Tracey, 2012), and affect and perceptions at work (e.g., Spector, 1987). Previous research has shown that leaving out the general factor of response bias would contribute to model misfit (Hopwood & Donnellan, 2010; Rounds & Tracey, 1993).

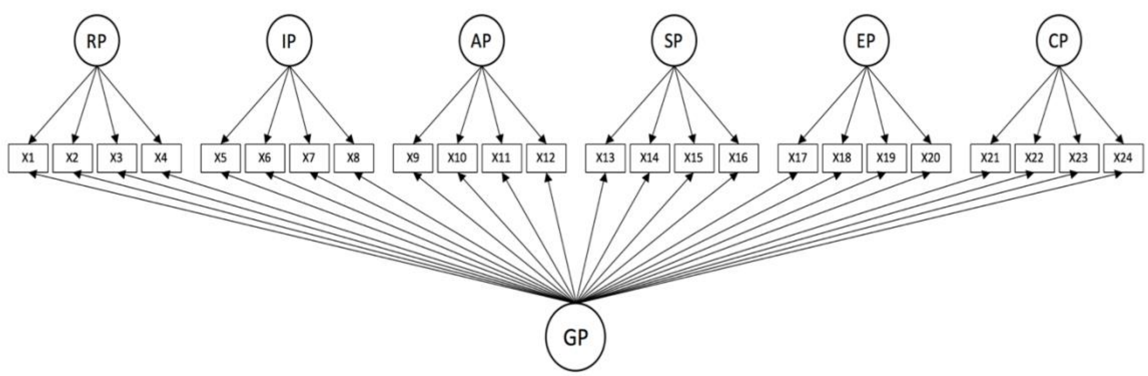

Figure 1. Bi-factor model of perceptions of engineering. [Note: X denotes perception items; RP, IP, AP, SP, EP, and CP denote perception subscales of realistic, investigative, artistic, social, enterprising, and conventional, respectively; GP denotes the general perception factor. For the sake of clarity, residuals are not depicted in the figure.]

We conducted the bi-factor CFA with package lavaan (Rosseel, 2012) in R version 3.4.0 (R Core Development Team, 2017) with maximum likelihood estimation using the pre-intervention data of Sessions 1 and 2. The pre-intervention data was used because we were most interested in the intervention effect. In evaluating model fit, we used the comparative fit index (CFI), the Tucker-Lewis index (TLI), the root mean square error of approximation (RMSEA), and the standardized root mean residual (SRMR). Hu and Bentler (1998) has shown that these fit indices are fairly robust across methods of estimation and violation of normality. Values greater than .95 and .90 for CFI and TLI, RMSEA values of less than .05 and .08, and SRMR values less than .05 and .08 have been suggested as evidence for excellent and acceptable model fit (Browne & Cudeck, 1993; Hu & Bentler, 1999). The bifactor model with 6 perception subscale factors and a general factor fitted well to the data, with χ^2 = 325.029, df = 213, p < .01, CFI = .94, TLI = .92, RMSEA = .045 (90% confidence interval [CI] = [0.035, 0.055], p-value for RMSEA ≤ 0.05 is .779), and SRMR =.043. These results indicate that the perception of engineering assessment with 24 items had good structural validity and the items were good indicators of the six perception dimensions. Therefore, the F-PIPES we developed is validated and suitable for usage in our further analysis of intervention effects.

Fit between personal interests and perceptions of engineering. A student's level of interest fit with engineering was calculated using the profile correlation between the student's personal interests and his/her perception of engineering both before and after the intervention. It is simply Pearson's product-moment correlation, calculated using the equation below:

$$r_{xy} = \frac{\sum x_i y_i - n\bar{x}\bar{y}}{\sqrt{(\sum x_i^2 - n\bar{x}^2)}\ \sqrt{(\sum y_i^2 - n\bar{y}^2)}}.$$

where x_i represents a student's interests across Holland's six dimensions and y_i represents a student's perception of engineering across Holland's six dimensions. This index ranged from -1 to 1, with a larger value indicating a higher degree of fit. Profile correlation concerns the extent to which the pattern or shape of a person's interests is compatible with the pattern or shape of occupational characteristics across all the interest dimensions rather than the level or elevation of each interest dimension. Research using 10 interest inventories with 23 diverse samples of 53,429 respondents (Prediger, 1998) has shown that the level or elevation of interests reflects response style (i.e., a person's tendency to say yes to survey items) more so than it reflects the strength of interest. It is the pattern or shape of interest profile across six dimensions and its fit with the characteristics of academic fields that matter for academic performance and persistence

(Nye et al., 2012, 2017). Tracey (2012) recommended using profile correlation for indexing the degree of interest fit, as it has been shown to be superior than other types of congruence indices (for a review, see Camp & Chartrand, 1992 and Brown & Gore, 1994). The use of profile correlation for indexing interest fit has been validated and has received empirical support from a plethora of large-scale studies (e.g., Allen & Robbins, 2010; Le, Robbins, & Westrick, 2014; Tracey & Robbins, 2006), demonstrating its significant relationships with academic choice, academic performance, and persistence.

Interest in engineering. Participants' interest in engineering was measured with two items, "I like engineering" and "Engineering is exciting to me". Participants were asked to indicate the extent to which they agreed with each item with a 5-point scale, of which "1" represented "Strongly disagree" and "5" represented "Strongly agree". This measure was reliable in the current sample, with a Cronbach's α of .79 for both pre- and post-intervention surveys.

Table 3: Cronbach α Results for Engineering Perceptions Items

Items	Cronbach's ∝ pre/post	Items	Cronbach's ∝ pre/post
Realistic	.68/.75	*Social*	.68/.75
1. Work with gadgets		**1. Protect the environment**	
2. Build roads, buildings, or bridges		**2. Protect animals**	
3. Fix broken things		**3. Teach others**	
4. Make electronic devices		**4. Make the world a better place**	
Investigative	.69/.77	*Enterprising*	.72/.75
1. Use math to solve problems		**1. Start a business**	
2. Figure out why things don't work		**2. Supervise groups of people**	
3. Learn how things work		**3. Organize business agreements**	
4. Develop new ways to solve problems		**4. Sell products**	
Artistic	.75/.73	*Conventional*	.69/.69
1. Use their imagination		**1. Enforce rules**	
2. Use colors and shapes		**2. Keep records for future reference**	
3. Draw, sketch, doodle or paint		**3. Write reports**	
4. See the bigger picture		**4. Document their work**	

Conclusion

The F-PIPES instrument is intended for use with engineering curriculum or activities that aim to improve their intervention's appeal to young students. Like any survey instrument, F-PIPES does not provide definitive answers, but can help suggest what might be working well and not so well in an engineering intervention. The F-PIPES instrument can also be helpful in better understanding the students being served by an intervention and identify opportunities to appeal to their interests in a more targeted manner. We see it as a formative feedback tool that should be combined with other feedback methods (e.g., observations, student interviews/reflections, etc.). As previously mentioned, our philosophy is to present engineering as a broad field that can address all the RIASEC interest dimensions as opposed to only highlighting the areas that relate to students' personal interests. Going forward more testing with different student populations, different engineering interventions, and other varying contextual factors needs to be done to further validate the utility of this tool.

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References

Allen, J., & Robbins, S. (2010). Effects of interest–major congruence, motivation, and academic performance on timely degree attainment. *Journal of Counseling Psychology, 57,* 23–35.

American Educational Research Association, American Psychological Association, & National Council on Measurement in Education (AERA, APA, & NCME). (2014). *Standards for Educational and Psychological Testing*: AERA.

Aschbacher, P. R., & Tsai, S. M. (2014). Gender differences in the consistency of middle school students' interest in engineering and science careers. *Journal of Pre-College Engineering Education Research (J-PEER), 4*(2), 2.

Atkinson, R. C., Wickens, T. D., & Glaser, R. (1971). Human memory and the concept of reinforcement. *The nature of reinforcement*, 66-120.

Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ*, *1986*.

Black, K. (1994). An industry view of engineering education. *Journal of Engineering Education, 83*(1), 26-28.

Bolles, R. C., & Zeigler, H. P. (1967). *Theory of motivation*: Harper & Row New York.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education*, *97*(3), 369-387.

Brown, S. D., & Gore, P. A., Jr. (1994). An evaluation of interest congruence indices: Distribution of characteristics and measurement properties. *Journal of Vocational Behavior, 45*(3), 310-327.

Camp, C. C., & Chartrand, J. M. (1992). A comparison and evaluation of interest congruence indices. *Journal of Vocational Behavior, 41*(2), 162-182.

Carr, R. L., Bennett IV, L. D., & Strobel, J. (2012). Engineering in the K-12 STEM Standards of the 50 US States: An Analysis of Presence and Extent. *Journal of Engineering Education, 101*(3), 1-26.

Clark, L. A., & Watson, D. (1995). Constructing validity: Basic issues in objective scale development. *Psychological assessment, 7*(3), 309.

Committee on Equal Opportunities in Science and Engineering (CEOSE). (2017). *2015-16 Biennial Report to Congress: Broadening Participation in America's STEM Workforce*. Retrieved from https://www.nsf.gov/od/oia/activities/ceose/index.jsp

Deci, E. L. (1992). The relation of interest to the motivation of behavior: A self-determination theory perspective *The role of interest in learning and development* (pp. 43-70). Hillsdale, NJ: Lawrence Erlbaum Associates.

Donnay, D. A. C., Morris, M. L., Schaubhut, N. A., & Thompson, R. C. (2005). *Strong Interest Inventory manual: Research, development, and strategies for interpretation*. Mountain View, CA: CPP.

Eccles, J. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist*, *44*(2), 78-89.

Eccles, J., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In Spence, J. T. (Ed.), *Achievement and achievement motives*. San Francisco, CA: W. H. Freeman.

Eccles, J. S., Wigfield, A., & Schiefele, U. (1998). Motivation to succeed.

Edwards, J. R., Cable, D. M., Williamson, I. O., Lambert, L. S., & Shipp, A. J. (2006). The phenomenology of fit: linking the person and environment to the subjective experience of person-environment fit. *Journal of applied Psychology*, *91*(4), 802.

Elam, M. E., Donham, B. L., & Solomon, S. R. (2012). An engineering summer program for underrepresented students from rural school districts. *Journal of STEM Education: Innovations & Research*, *13*, 35-44.

Figueiredo, A. (2008). *Toward an epistemology of engineering.* Paper presented at the 2008 Workshop on Philosophy and Engineering, The Royal Academy of Engineering, London.

Fraser, B. J. (1978). Development of a test of science-related attitudes. *Science Education, 62*(4), 509-515.

Gibbin, R. D., & Davis, L. A. (2002). *Raising public awareness of engineering*: National Academies Press.

Harackiewicz, J. M., Rozek, C. S., Hulleman, C. S., & Hyde, J. S. (2012). Helping parents to motivate adolescents in mathematics and science: An experimental test of a utility value intervention. *Psychological Science, 23,* 899–906.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational research*, *60*(4), 549-571.

Holland, J. L. (1997). *Making vocational choices: A theory of vocational personalities and work environments* (3rd ed.). Odessa, FL: Psychological Assessment Resources.

Holland, J. L., Fritzsche, B., & Powell, A. (1994). *Self-Directed Search: Technical manual*. Odessa, FL: Psychological Assessment Resources.

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology*, *102*(4), 880-895.

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and performance in high school science classes. *Science, 326,* 1410–1412.

Hynes, M. M., Joslyn, C., Hira, A., Holly, J., & Jubelt, N. (2016). Exploring diverse pre-college students' interests and understandings of engineering to promote engineering education for all. *The International journal of engineering education*, *32*(5), 2318-2327.

Hynes, M. M., Mathis, C., Purzer, S., Rynearson, A., & Siverling, E. (2017). Systematic review of research in P-12 engineering education from 2000–2015. *International Journal of Engineering Education*, *33*(1), 453-462.

Knight, M., & Cunningham, C. (2004a). *Draw an Engineer Test (DAET): Development of a tool to investigate students' ideas about engineers and engineering.* Paper presented at the ASEE Annual Conference and Exposition.

Knight, M., & Cunningham, C. (2004b). *Draw an engineer test (DAET): Development of a tool to investigate students' ideas about engineers and engineering.* Paper presented at the ASEE Annual Conference and Exposition.

Krapp, A., Hidi, S., & Renninger, K. A. (1992). Interest, Learning, and Development. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Kristof-brown, A. L., & Billsberry, J. (2013). Fit for the future. In A. L. Kristof-brown & J. Billsberry (Eds.), *Organizational fit: Key issues and new directions* (pp. 1-18). West Sussex: John Wiley and Sons.

Le, H., Robbins, S. B., & Westrick, P. (2014). Predicting student enrollment and persistence in college STEM fields using an expanded PE fit framework: A large-scale multilevel study. *Journal of Applied Psychology*, *99*(5), 915-947.

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of vocational behavior*, *45*(1), 79-122.

Linnenbrink, E. A., & Pintrich, P. R. (2002). Motivation as an enabler for academic success. *School Psychology Review, 31*(3), 313-327.

Messick, S., & Jackson, D. N. (1961). Acquiescence and the factorial interpretation of the MMPI. *Psychological Bulletin*, *58*(4), 299-304.

Miaoulis, I. (2014). K-12 Engineering: The Missing Core Discipline. In Ş. Purzer, J. Stroble, & M. E. Cardella (Eds.), *Engineering in Pre-college Settings* (pp. 21-33). West Lafayette, IN: Purdue University Press.

National Academy of Engineering. (2008). *Changing the Conversation: Messages for Improving Public Understanding of Engineering*: National Academy Press.

National Research Council (NRC). (2009). *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* Retrieved from Washington DC:

National Science Foundation, & National Center for Science and Engineering Statistics. (2017). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017*. Retrieved from Arlington, VA: http://www.nsf.gov/statistics/wmpd/:

Nye, C. D., Su, R., Rounds, J., & Drasgow, F. (2012). Vocational interests and performance: A quantitative summary of over 60 years of research. *Perspectives on Psychological Science*, *7*, 384–403.

Nye, C. D., Su, R., Rounds, J., & Drasgow, F. (2017). Interest congruence and performance: Revisiting recent meta-analytic findings. *Journal of Vocational Behavior, 98*, 138-151.Pajares, F., & Urdan, T. (2005). Self-efficacy and adolescence. *A volume in Adolescence and Education*.

Paulhus, D. L., & Vazire, S. (2007). The self-report method. In R. W. Robins, R. C. Fraley, & R. F. Krueger (Eds.), *Handbook of research methods in personality psychology* (pp. 224-239). New York: Guilford.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology, 95*(4), 667.

Prediger, D. J. (1998). Is interest profile level relevant to career counseling? *Journal of Counseling Psychology*, *45*(2), 204-211.

Renninger, A., Hidi, S., & Krapp, A. (Eds.). (1992). *The role of interest in learning and development*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Rounds, J., Ming, C. W. J., Cao, M., Song, C., & Lewis, P. (2016). Development of an O* NET® Mini Interest Profiler (Mini-IP) for Mobile Devices: Psychometric Characteristics.

Rounds, J., Su, R., Lewis, P., & Rivkin, D. (2010). *O*NET Interest Profiler Short Form Psychometric Characteristics: Summary and Supporting Evidence*. U.S. Department of Labor National O*NET Resource Center.

Schiefele, U. (2012). Interests and learning *Encyclopedia of the Sciences of Learning* (pp. 1623-1626): Springer.

Schiefele, U., Krapp, A., & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analysis of research.

Sneider, C., & Purzer, S. (2014). The Rising Profile of STEM Literacy Through National Standards and Assessments. In Senay Purzer, Johannes Strobel, & M. E. Cardella (Eds.), *Engineering in Pre-College Settings*. West Lafayette, IN: Purdue University Press.

Spector, P. E. (1987). Method variance as an artifact in self-reported affect and perceptions at work: Myth or significant problem? *Journal of Applied Psychology, 72*(3), 438-443.

Su, R., Murdock, C., & Rounds, J. (2015). Person-environment fit. *APA handbook of career intervention, 1*, 81-98.

Thompson, S., & Lyons, J. (2008). Engineers in the Classroom: Their Influence on African-American Students' Perceptions of Engineering. *School Science & Mathematics, 108,* 197-211.

Tracey, T. J. G. (2012). Problems with single interest scales: Implications of the general factor. *Journal of Vocational Behavior, 81*, 378–384.

Tracey, T. J. G., & Robbins, S. B. (2006). The interest–major congruence and college success relation: A longitudinal study. *Journal of Vocational Behavior*, *69*, 64–89.

Wulf, W. A. (2006). Diversity in engineering. *Women in Engineering ProActive Network*.