Board 120: Development of an Engineering Identity and Career Aspirations Survey for Use with Elementary Students

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Introduction

Due to the underrepresentation of women and minorities in engineering fields, significant attention has been focused on understanding how and why individuals develop an engineering identity. Interest in science, technology, engineering, and mathematics (STEM) begins as early as elementary and middle school [1-4]. As youth enter adolescence, they begin to shape their personal identities and start making decisions about who they *are* and *could be* in the future. Children as young as elementary school have already formed career aspirations and interests related to STEM [5-6], with such decisions appearing long before having to choose coursework in high school or college. However, engineering identity formation is an emerging field, and much of the research to date has focused on high school or post-secondary students [7]. Efforts to attract and retain historically underrepresented youth in engineering rely on the extent to which these individuals see themselves as someone who does engineering [8]. As a result, recent research in engineering education focuses specifically on engineering identity [9, 10].

An individual's identity consists of interrelated identities that define one's personal, social, and role-related identities [11]. It is the role-related identity that is the focus of the current study as it represents one's identity within a specific field of study or work, such as engineering. Much of the research on role-related identities has examined the development of an individual's "science" identity, with one of the most cited frameworks being that of Carlone and Johnson [12], which posits that one's science identity consists of the interrelationship among *performance*, *competence*, and *recognition*. Building on this framework and drawing from a social-cognitive perspective, Hazari and colleagues [11] added a fourth component when they examined students' physics identity, namely *interest*, which reflects one's desire or curiosity in a subject [11, 13-14]. While these components were developed within the context of specific roles (e.g., science, physics), they reflect general aspects of one's role-related identity, and therefore they are applicable to specific fields beyond science. Drawing from this framework, this paper describes the development of a survey instrument that contributes to understanding engineering identity development and career aspirations in elementary students. We draw from work on both engineering and science identity development throughout.

Current Study

Studies that examine the development of one's engineering and science identity often utilize interviews or case-study methodology [8, 15-16]. While informative, such approaches often are not pragmatic in classroom settings with large numbers of students when the goal is to learn about or examine changes in students' STEM identities and aspirations in general or after using a STEM-related program or curriculum [17]. Existing surveys that assess identity often target high school or post-secondary students [18-19] with much less work on elementary and middle school students [5]. Similar to work on identity, assessment of career aspirations used a variety of methods (including interviews and surveys), and often ask students whether they want to be a scientist or to "do" science [11], use a checklist to select from broad science career categories, or have students list the job they want when they grow up [20]. Elementary and middle school students often have a limited or nascent awareness of what engineers do or misconceptions about what a job in science or engineering entails [21-22]. Similarly, using checklists or broad career categories presents difficulties as students may have varying levels of interest in different careers within those categories, and the categories may not align well with STEM careers [23]. The survey instrument we describe in this paper seeks to address some of these limitations and provide a practical tool for assessing engineering interest and identity in elementary school students.

Methods and Procedures

Developed within the context of a multi-year, NSF-funded research project to understand the impact of an engineering outreach program on students' engineering identity and career aspirations, items were drawn and adapted from existing measures of STEM identity and career aspirations when possible. Development of the survey occurred in three phases. Participants in all phases of survey development were elementary students enrolled in 3rd-6th grade. IRB approval and participant consent were obtained prior to data collection. Phases 1 and 2 were conducted with suburban students participating in the engineering outreach program in Massachusetts (n = 80 and 89, respectively). Phase 3 was conducted with students enrolled in urban, suburban, and rural classrooms in Indiana and Massachusetts (n = 323).

Phase 1: Initial Data Collection

In Phase 1, we utilized the 16-item revised Engineering Identity Development Scale (EIDS) which measured three components of identity: academic identity, occupational identity, and engineering aspirations [24]. The EIDS was selected initially due to having been validated with elementary students within an engineering context. Review of Phase 1 data suggested limitations with the EIDS for measuring the desired constructs. Specifically, the full response scale was not utilized on most items, scale reliabilities (Cronbach's α) were lower than desired on one scale, and we found inconsistent factor loadings and multiple cross-loading items. Finally, literature review suggested the importance of including constructs related to identity not measured by the EIDS, specifically *recognition*, *interest*, and *performance/competence*.

Phase 2: Revision and Pilot Testing

Based on findings from the Phase 1, we revised the survey instrument in three ways: 1) response options were changed to a 4-point scale; 2) the academic identity scale of the EIDS was eliminated; and 3) 12 items were added based on a literature review. New items primarily were adapted from Godwin's [25] measure of engineering identity which was designed to assess engineering identity in post-secondary students, with an additional item drawn from the Engineering Interest and Attitudes Survey (EIA) [26]. Both instruments had been validated in engineering contexts and included items that assessed constructs identified in the literature. The new items assessed: *recognition* (4 items), *interest* (5 items), and *performance/competence* (3 items). This version of the survey consisted of 22 items.

Examination of data from Phase 2 pilot testing found greater variance using the 4-point scale with all four response options used for almost all items. Scale reliabilities (Cronbach's α) were within acceptable ranges for four of the five scales (ranged from $\alpha = 0.74 - 0.83$), though the occupational identity scale had lower than acceptable reliability ($\alpha = 0.51$).

Phase 3: Continued Survey Revision and Pilot Testing
During Phase 3, we retained all of the newly added items related to recognition, interest, and self-efficacy and all of the engineering aspirations items from the EIDS, but we dropped the occupational identity items. Our goal was to create a survey that was long enough to adequately assess the constructs of interest but short enough to be practical for administration in a classroom setting. To do so, we needed to pilot a large number of items in order to reduce them to 4 to 5 items per construct. Therefore, we created a larger pool of items to assess each construct, drawing and adapting items from a variety of existing, previously validated measures including the STEM Fascination and Competence/Self-efficacy Scales [27-28], the STEM Career Interest Survey (STEM-CIS) [29], the Modified Attitudes toward Science Inventory (M-ATSI) [30], and the Persistence Research in Science & Engineering survey (PRiSE). We selected items from these instruments to address unique aspects of the constructs of interest within the engineering context. When possible, we tried to select entire scales from validated instruments. Therefore, we did not select items from other existing measures when they were redundant with items already included from an intact scale. We added 21 items in the following areas: *performance/competence* (8 items), *STEM fascination* (6 items), *interest* (4 items), *outcome expectations* (2 items), and *recognition* (1 item). This survey version consisted of 37 items.

Assessing the extent to which students want to be an engineer assumes that they are aware of what such a career entails. Research suggests this assumption may be false. Therefore, similar to other researchers [21-22] and to address the limitations previously discussed, we added 38 items to assess the types of activities that students are interested in doing as part of a future career rather than asking them to choose a career from a checklist. So that we did not prejudice responses toward engineering, we included items that represented both non-STEM and STEM (both general and engineering-specific) activities. These items were created by the research team or adapted from existing research [21, 31-33], and we tried to align the STEM activities to STEM careers when possible. A second set of items to assess students' career interests drew from Holland's work on six personality types and the career activities associated with them: realistic (R), investigative (I), artistic (A), social (S), enterprising (E), and conventional (C) [34]. We adapted items from the O*NET Interest Profiler [35-36] that assesses career/vocational interests based on these RIASEC types. We sought to reduce the number of items by having students pick the O*NET-derived activity they most preferred within a set that included an option from each RIASEC category rather than rating all items. We presented five sets of 6 activities each, and then a final set that populated with the previously chosen activities and asked students to choose which activity of those that they were most interested in. In this format, instead of responding to 30 individual items, students only responded to six.

Content and pedagogical experts (including elementary teachers and researchers) reviewed the items for readability and construct coverage. Because we drew from validated instruments, we sought to keep item wording as close as possible to the original wording. However, minor wording changes were made to simplify and make items age-appropriate for elementary students. Despite efforts to make items more age-appropriate, due to the nature of the content of the questions, the readability skews toward older students.

We used exploratory factor analysis (EFA) and scale reliability analysis to identify underlying factors and to further reduce the number of items separately for the identity and career aspirations items. Principal Components Analysis with oblique rotation was selected as we expected the factors to be related to one another [37]. Pairwise deletion was used to maximize the sample size available for each comparison. Utilizing iterative rounds of EFAs, we eliminated items that did not load on any factor within each round. This process continued until all items loaded on at least one factor with a loading of 0.40 or higher. These iterations resulted in a 5-factor model (24 items) for identity and a 6-factor model (30 items) for career aspirations.

Results

Engineering Identity. Our data yielded a 5-factor model which expanded on the three components identified in the literature. (See Appendix for information on factors and sample items). While we expected to find one factor that represented recognition, two factors emerged: *Recognition by Others* and *Self-Recognition*. This is consistent with prior work that suggests that while recognition by others is important in identity development, just as important is whether one views one's self as an "engineering person" (self-recognition) [12]. The *Interest* factor captured an individual's enjoyment in doing engineering activities, while the *Performance/Competence* factor reflected students' beliefs in their ability when doing engineering activities. Both factors are similar to constructs found in the literature [11-12, 25]. We found a fifth factor in our data that warrants additional research. On the surface, this factor seems to represent *Perceptions of Difficulty in Engineering*, as all items on this factor are negatively worded items (e.g., I don't understand engineering). While these items could reflect a perception related to the difficulty of engineering, it is possible that these items all load on one factor simply due to the negative wording. In other words, if the items had been worded positively (e.g., "I understand engineering"), they might have loaded on another factor (e.g., Performance/Competence). Negatively worded items have been found to be psychometrically problematic due to the added level of difficulty when answering them. Some researchers have found that negatively worded items create distinct, albeit artificial, factors [38-40]. Future work is needed to further differentiate between interest, performance/competence, and self-efficacy as there is overlap among these constructs, and future work also is needed to investigate the factor comprised of only negative items. Continued pilot testing with additional items for constructs with fewer than 4 items currently is in progress. Utilizing item response theory (IRT) may help to further refine and improve the robustness of the scales.

Interest in Career Activities (Career Aspirations). Our results indicated a 6-factor solution with one factor representing non-STEM activities and the other five factors representing various STEM activities related to: *science/engineering*, *helping others/social*, *mechanical or stereotypical engineering* (e.g., designing, building, fixing), *environment*, and *problem solving and analysis*. This suggests that students have varying interests related to STEM that might not be discovered if asked using broad categories or checklists of engineering or STEM careers. Research suggests that elementary and middle school students have a limited understanding of the type of work and range of careers within engineering [21-22]. If students have a narrow conception of what an engineer does (e.g., build robots), if they are not interested in that type of work and are asked, "Do you want to be an engineer?", the likely response will be negative.

However, this response may be misleading as these same students may, in fact, be interested in activities that engineers do but they simply are not aware that engineers do them. A next step would be to ask students to rate their interests in activities as well as if they think engineers do these activities as part of their jobs. This will enable comparisons between students' interests and their perceptions of what a career in engineering entails, potentially helping us identify students who might otherwise indicate a lack of interest in engineering simply because they do not know what engineers do.

Interest Profiles (Career Aspirations). The data collected on the six RIASEC items have potential in terms of creating individual interest profiles for students. Preliminary examination of the patterns of activities chosen by students were conducted by summing the number of times students selected activities representing each RIASEC category and then creating a pattern of the sums. Students who have begun to narrow down their career interests would be represented by a pattern of similar interests (e.g., all or the majority of items selected are of the same or related RIASEC types). For example, one possible pattern could be 2-4-0-0-0-0 (i.e., the student selected two "R" and four "I" items), and suggests that interests have been narrowed down to two areas of interest, as the pattern includes only two of the six Holland Codes. Students who have not yet begun to narrow down their interests likely would have multiple RIASEC codes represented with no clear pattern exhibited. For example, a pattern of 2-2-0-1-1-0 would have selected two "R", two "I", zero "A", one "S", one "E", and zero "C" items, which does not clearly identify a single area of interest. However, having only six sets of items does not provide a sufficient number of items from which to identify a clear preference. In many cases, students expressed interest in four or more different codes. While it is assumed (and desirable) that students at this age have a variety of interests, in order to see if patterns of interest have begun to form, additional items are needed. Continued pilot testing with additional item sets is needed and currently is in progress.

Conclusions

The current survey was developed within the context of a project that seeks to better understand the impact of an engineering outreach program on students' engineering identity and career aspirations. In assessing program impacts, the goal is to be able to make claims about the effectiveness of the program or outreach project in shifting students on the targeted outcomes. However, the data to answer this question are only as good as the measure used to collect them. We needed a measure that accounted for the emerging understanding of engineering careers held by adolescent students who are only beginning to think about possible future careers. Therefore, our goal was to develop an instrument that assessed aspects of engineering identity and career aspirations in multiple ways and that could be used easily in classrooms or outreach programs to better gauge program impact. While further testing and refinement of the survey are needed, we are progressing toward that goal. Our survey informs research related to constructs of engineering identity, especially for adolescent students as they start to narrow down possible future careers and make decisions to move them along those pathways.

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Appendix

Table. Instrument Factors and Example Items

Factors	Scale Reliability	Example Item
	Engineering Identity	
Enjoyment/Interest (*n* = 6)	α = 0.79	"I love designing things!"
Self-recognition (*n* = 5)	α = 0.91	"I see myself as an engineer."
Negative Perceptions of Engineering (*n* = 3)	α = 0.68	"I don't understand engineering."
Self-efficacy/Competence (*n* = 7)	α = 0.85	"I am able to do well in activities that involve engineering."
Recognition by Others (*n* = 3)	α = 0.83	"My friends see me as an engineer."
	Interest in Career Activities	
Science/Engineering (*n* = 8)	α = 0.92	"Figure out how things work."
Helping Others/Social (*n* = 6)	α = 0.84	"Improve bandages."
Mechanical/Stereotypical Engineering (*n* = 5)	α = 0.81	"Repair cars."
Environment (*n* = 3)	α = 0.75	"Study animals or wildlife."
Problem-solving and Analysis (*n* = 5)	α = 0.86	"Analyze and interpret data."
Non-STEM (*n* = 3)	α = 0.66	"Manage a store or business."
	Interest Profiles	
RIASEC (*n* = 6) *Realistic, Investigative, Artistic, Social, Enterprising, Conventional*	N/A	[*Choose option you are most interested in*] "Help people with personal or emotional problems" "Develop a new medicine." "Load apps and programs onto computer systems." "Manage a department within a large company." "Build kitchen cabinets." "Write books or plays."