The Development of the STEM Career Interest Survey (STEM-CIS)

Abstract

Many countries across the globe seek to recruit more students in science, technology, engineering, and mathematics (STEM) careers to stimulate economic growth and generate new ideas and perspectives within these fields. Scientific and educational organizations recommend that efforts to interest students in STEM majors and careers begin at the middle school level, a time when students are developing their own interests and recognizing their academic strengths. Given international efforts to increase STEM interest and preparation, there is a need for instruments that effectively measure interest in STEM classes and careers, especially for middle school students. In response to calls in the literature, we developed a survey with subscales in science, technology, engineering, and mathematics, based on aspects of the social cognitive career theory. In this manuscript we detail the six stages of development of the STEM Career Interest Survey (STEM-CIS) and investigate its reliability and psychometric properties in measuring middle school students’ STEM career interests. We gave this 44 item survey to over 1000 middle school students (grades 6-8) who primarily were in rural, high poverty districts in the southeastern US. Confirmatory factor analyses indicate the STEM-CIS is a strong, single factor instrument and also has four strong, discipline specific subscales which allow for the science, technology, engineering, and mathematics subscales to be administered separately or in combination. We believe this instrument will help researchers, professional developers, and evaluators to measure STEM career interest and the effects of STEM programs on changes in student interest in STEM subjects and careers.
Introduction

Many countries around the world face the task of recruiting more individuals into science, technology, engineering, and mathematics (STEM) industries (Hill, Corbett, & St. Rose, 2010; Regisford, 2012). Global statistics from the United States (US) and other nations highlight the untapped resources for STEM in women and minorities who are not currently majoring in or working in these fields (Henriksen, 2013). Within the workforces of Austria, Chile, Czech Republic, France, Germany, Honduras, Mexico, Netherlands, and Switzerland, women comprise only 30% of all research scientists. Similarly, in the US, labor statistics project the development of nearly three million new jobs in science and technology by 2020, requiring capable individuals with educational backgrounds in STEM to fill these positions (Bureau of Labor Statistics, 2010; National Science Board, 2010). Currently, only 20% of all US bachelor’s degrees in physics, engineering, and computer science are earned by women, and only 15% by African Americans and 18% by Hispanics (National Center for Educational Statistics, 2012; United States Congress Joint Economic Committee, 2012).

Policy leaders around the world are creating partnerships with large businesses and organizations to recruit more teachers in science, technology, engineering and mathematics (STEM) areas, with the goal of engaging and advancing more students in STEM, expanding career opportunities for females and minorities, and creating future STEM innovations (e.g. Change the Equation, 2010; Tech Women, 2013; Regisford, 2012; White House Office of Science and Technology Policy, 2012). A variety of reports suggest reasons for these disparities within the STEM workforce, including: a lack of quality preparation in mathematics and science
in K-12 educational systems, lack of access to money and technology, lack of guidance from adults who are knowledgeable of or affiliated with STEM careers, psychological barriers, such as believing math and science are too difficult, and lack of role models in the fields (Drew, 2010; National Academy of Sciences, Global Affairs & Institute Of Medicine, 2011; Scott and Martin, 2012).

Studies document a decline in STEM interest from elementary school to late high school, but few studies have measured why student interest in STEM subjects or careers changes (and often declines) prior to entering college (Fouad, Smith, & Enoch 1997; VanLeuvan, 2004). Educational testing organizations and some researchers suggest the use of STEM career interventions in the classroom to build interest in STEM careers, beginning at the middle school level (e.g. ACT, 2011; Skamp, 2007). When elementary and middle school students are engaged in discussions about goals and opportunities available in STEM, they have time to connect their interests to these subjects, and demonstrate higher self-efficacy in these fields prior to college (Subotnik, Edminster & Rayhack, 2007).

Studies that have used in-school and out-of-school interventions designed to connect underrepresented students to STEM professionals and careers show promise of increasing awareness and interest in STEM careers (Author, 2010; Avery, 2013). Specifically, interventions that include STEM role models have been found very effective in increasing students’ engagement, and creating accurate perceptions of STEM with students at the secondary and post-secondary level (Ashby Plant, Baylor, Doerr, & Rosenberg-Kima, 2009; Stout, Dasgupta, Hunsinger, & McManus, 2011; Zeldin, Britner & Parajes, 2008). When examining the literature in counselor education and STEM education, few instruments to date have been developed to measure the construct of interest in STEM careers in general, and specifically at the middle
school level (Whitfield, Feller, & Wood, 2008), an age when students are forming career beliefs (ACT, 2011; Skamp, 2007).

Tyler-Wood, Knezek and Christensen (2010) address this gap with two instruments, the *STEM Semantics Survey* and the *STEM Career Questionnaire*, which measures student interest in science, technology, engineering, and mathematics, STEM careers, and interest in broad science areas. The researchers validated the *STEM Semantics Survey* with a population that ranged in age from middle school to adult. Their *STEM Semantics Survey* contains five pairs of opposing adjectives within each subject area and for STEM careers as a whole. For example, students rank on a seven point Likert scale if they feel that science is better described as fascinating (1) or mundane (7). Their calculated Cronbach’s alpha for Cronbach’s alphas for science, technology, engineering, mathematics and general STEM careers ranged from .84 to .93. They suggest using this survey in combination with validated constructs from Bowdich’s (2009) *Career Interest Questionnaire* (CIQ). The CIQ constructs adapted by Tyler-Wood, Knezek, & Christensen consisted of 12 items that measured perception of supportive environment for pursuing a career in science, interest in pursuing educational opportunities that would lead to a career in science, and perceived importance of a career in science. Cronbach’s alphas were established for 60 middle school students and ranged from 0.78 to 0.94. Their use of exploratory factor analysis on both surveys provides strong implications that these items are effective in measuring interest in STEM. However, neither survey was explicitly linked to theoretical frameworks.

Lent, Brown, & Hackett (1994) developed a promising theoretical model to predict interest and intent to pursue academic choices and careers, the social cognitive career theory (SCCT). This model allows researchers to use measures of individual’s self-efficacy, outcome
expectations, personal inputs and backgrounds, and contextual supports and/or barriers to explain reasoning behind students’ academic or career choices. Studies that have utilized this theory as a predictive model of interest for STEM fields have predominately been at the secondary and post-secondary level. However, as no STEM career interest survey existed, these researchers used a variety of surveys that measured one or more aspects of the SCCT such as a survey on the nature of learning experiences in math class (Hill, 2011), self-efficacy in science and mathematics (Fouad, Smith, & Enoch, 1997, and intent to pursue careers in information technology (Stone, Johnson, Stone-Romero, & Navas, 2005). Another method for incorporating aspects of the SCCT to predict student interest in science and math has used imputed school based data into the model (e.g. Navarro, Flores, and Washington)

Navaro, Flores, and Washington (2007) investigated science and math interest in Mexican American middle school students, using generation status, socio-economic data from the district, and separate surveys on outcome expectations and self-efficacy from the students. Whitfield, Feller and Wood (2008) have identified ten instruments to measure career interests, but four of these use normative data, and none of them focus on STEM careers. No study to date has used the social cognitive aspects to develop a survey measuring interest and intent to pursue academic choices or careers in STEM for middle school students. Therefore, given the utility of this theoretical framework, we have developed a survey measuring interest in each subject area with aspects derived from the SCCT. We believe the STEM Career Interest Survey (STEM-CIS) instrument will help researchers in professional development and evaluators to measure the effects of their STEM programs on changes in student interest in STEM subjects and careers, with implications for STEM intervention design and changes.

**Literature Review**
Student Interest in STEM

Few research studies have investigated important influences on STEM career interest for middle school students, compared to the secondary and post-secondary level (Usher, 2009). Findings suggest that middle school and high school students are interested in science but have a lesser desire to become a scientist (Kitts, 2009). These interests have also been found to differ by gender. For instance, when examining what questions high school and middle school students ask in an Ask a Scientist website, males were more likely to ask questions about the physical sciences and females were more inclined to ask about the biological sciences (Baram-Tsabari 2007, 2008; Baram-Tsabari, Sethi, Bry, & Yarden, 2009). Research by Brotman and Moore (2008) found that 8th grade females reported they had fewer informal experiences with science than did males.

Perceptions of STEM professionals and careers

Studies that address the perceptions of K-12 students in regards to their perceptions of STEM careers and professionals suggest that students have little experience with these careers (Masnick, Valenti, Cox & Osman, 2010). Inaccurate stereotypes of STEM professionals begin at an early age; one study found that elementary students commonly drew and described engineers as men, and someone who fixes things similar to a mechanic (Capobianco et al., 2011). The trend continues in the secondary years with abstract descriptions and drawings of engineers. In a number of studies, high school students reported that they believe an engineer to be male, someone who works on cars, someone who fixes or builds things, someone who fixes electronics, and someone that designs. (Bouchey & Harter, 2005; Burke & Mattis, 2008; Capobianco, Diefes-Dux, Mena & Weller, 2011; Fralick, Kearn, Thompson & Lyons, 2009; Thomas & Allen, 2006). Similar to the engineer prototypes, stereotypic views were seen in the
scientist drawings of high school students, with over half being white males drawn doing experiments in a lab (Fralick, et al., 2008).

Thomas and Allen (2006) investigated why Australian undergraduates decided not pursue instruction technology (IT) careers after extensive training in high school. Likert scale survey results found students believe that professionals in these careers do technical work on a computer all day and have few opportunities to work with others. Johnson & Miller (2002) assert that these careers are not attractive to students, particularly females, because of the manner in which they are advertised (i.e., a men-only environment, long hours that would not be conducive to a family). They believe that jobs IT fields need to be more clearly articulated to attract more diverse individuals. Some components of effective interventions that document an increase STEM engagement and interest include having real and virtual role models and presenting information on the balance of work, a social life and a home life (Ashby, et al., 2009; Buck, Clark, & Leslie-Pelicky, Lu, & Cerda, 2008; Millward, Houston, Brown, and Barrett, 2006; Rosenberg-Kima, Baylor, Plant, & Doerr, 2008; Zeldin, Britner, & Parajes, 2008).

**Theoretical Framework**

Lent, Brown and Hackett provide a promising theoretical framework and predictive model on interest and career choice. The social cognitive career theory (SCCT; Lent, Brown, & Hackett, 1994; 2000) is based on Bandura’s (1986) social cognitive theory of learning. Bandura (1986) theorized that individuals exhibit two loci of control over their own actions: internal and external. Internal refers to how individuals control their own actions; external is how they negotiate societal interactions and influences. According to Bandura, the most influential personal control over action is self-efficacy, an individual’s belief that they are capable of mastering events within their lives. For example, a student with high science self-efficacy may
believe that she is able to earn a good grade in her science class. Self-efficacy is involved in setting personal goals, analyzing decisions and making commitments.

Lent, Brown and Hackett (1994) connect Bandura’s relationship between self-efficacy, outcome expectations and goals to contextual factors, personal inputs and interests to explain how individuals make career-related decisions (see Figure 1). In the model, personal inputs are socially constructed factors, such as gender, background, race and socio-economic status and intrapersonal factors, such as personality, that contribute to one’s feelings of high or low self-efficacy. Contextual supports and barriers are external factors or individuals that either facilitate or impede high self-efficacy or setting academic or career goals. Studies that have used this framework encourage operationalizing these key aspects to be more relevant to the population that is being studied (Gushue, 2006; Lent, Lopez, Lopez & Sheu, 2008).

Figure 1. *The socio-cognitive career theory* (Lent, Brown, & Hackett 1994; 2000).
Research Question

Given that the predictive potential of the SCCT, we developed our survey instrument based on its key aspects (e.g. self-efficacy, outcome expectations, personal inputs, and contextual supports and barriers). The purpose of this study was to first develop, then to measure how this new instrument functioned in measuring factors related to middle school students’ interest in and goals related to STEM subjects and potential careers. Thus, here is the research question guiding this study:

*Is the STEM-CIS a reliable and psychometrically sound instrument for measuring middle school interest in STEM subjects and potential careers?*

Methodology

Clark and Watson (1995) identify six key components for developing scale items. For our study, we labeled each of their recommended steps as Stages 1-6 to help clarify the steps we took in the development of the STEM Career Interest Survey (STEM-CIS).

Stage 1: Conduct a literature review to help develop relevant items;
Stage 2: Create a broad item pool of items that will test the target aspect;
Stage 3: Preliminary pilot testing of items;
Stage 4: Conduct structural analysis to determine which items are to be eliminated from the pool of items;
Stage 5: Perform a factor analysis; and
Stage 6: Create subscales.

Context

The development of the STEM-CIS was to help us measure the impact of a professional development program. The STEM Career Awareness Project is an NSF-funded ITEST
(#1031118) project that emphasizes careers in the context of classroom instruction in rural, high poverty districts (approximately 80% free-and-reduced lunch) with approximately 85% minority students (see Table 1 for demographic data). One of the project activities was to have these middle school students use iPod® Touches to access 75 short, high quality STEM career videos (see Author, 2013 for a full description of the selection of the videos) that related to the classroom topic (e.g. cell biology; Cell Biologist career) and featured predominantly minority and female STEM professionals sharing work and life details, as recommended by the literature (Buck et al, 2008; Burke & Mattis, 2007; Millward et al., 2006) (wiki address for video site will be named after review). Alternately, teachers could show the video to the entire class. Career fact sheets and scripts were also created by the research team and on the school wiki, available to students and teachers. A survey instrument was needed to measure changes in student interest in STEM subjects and potential careers.

**Participants**

Data was collected from 1,061 students at seven middle schools in the rural southeastern United States (grades 5-8) to compile the data set used in this validation process (see Table 1 for school demographics). For all students, it was the first time they had seen the items (in some cases, students were only asked to take specific subscales). For instance, at School G, students took only the engineering subscale, as some had previously seen the items in other subscales. Students took the survey online using either an iPod touch® or a computer.
Table 1
Demographics of participant schools*

<table>
<thead>
<tr>
<th></th>
<th>Free and Reduced Lunch</th>
<th>African American</th>
<th>White</th>
<th>Hispanic</th>
<th>American Indian</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>School A</td>
<td>82.4</td>
<td>83.2</td>
<td>12.9</td>
<td>1.9</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>School B</td>
<td>85.1</td>
<td>71.6</td>
<td>24.6</td>
<td>2.5</td>
<td>0</td>
<td>1.3</td>
</tr>
<tr>
<td>School C</td>
<td>43.9</td>
<td>80.5</td>
<td>15.8</td>
<td>2.5</td>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>School D</td>
<td>76.6</td>
<td>67.7</td>
<td>16.7</td>
<td>3.4</td>
<td>9.2</td>
<td>6.0</td>
</tr>
<tr>
<td>School E</td>
<td>90.9</td>
<td>97.0</td>
<td>2.6</td>
<td>0</td>
<td>0</td>
<td>0.4</td>
</tr>
<tr>
<td>School F</td>
<td>59.4</td>
<td>40.5</td>
<td>51.4</td>
<td>2.8</td>
<td>0.4</td>
<td>4.9</td>
</tr>
<tr>
<td>School G</td>
<td>47.8</td>
<td>64.1</td>
<td>19.9</td>
<td>7.7</td>
<td>0</td>
<td>8.3</td>
</tr>
<tr>
<td>School H</td>
<td>51.9</td>
<td>42.6</td>
<td>38.6</td>
<td>7.4</td>
<td>1.7</td>
<td>9.7</td>
</tr>
</tbody>
</table>

Source: www.schooldigger.com – 2010-2011 school year *All numbers are in percentages.

Instrument Development

Stage 1: Literature Review

The literature review consisted of a search for studies addressing students’ interest in STEM and STEM careers, students’ perceptions of STEM professionals, and social cognitive career theory applied in math and science settings. The search included using ERIC, JSTOR, and Google Scholar and searching under the terms student STEM interest, instruments measuring STEM, students’ perceptions of STEM, and social cognitive career theory and STEM from the past ten years. Individual disciplines within STEM (science, technology, engineering, and mathematics were also searched to find literature regarding interest, perceptions of careers, measurements of interest, and social cognitive predictors of interest. Research from
approximately 130 articles was accumulated to write a larger review of STEM education, and select references were included in this manuscript. As previously described, findings suggested that interest in careers was often related to self-efficacy, outcome expectations, and previous learning experienced addressed by the Lent, Brown, & Hackett’s social cognitive career theory. The literature review and theoretical framework guided the development of our initial pool of survey items, as well as other instruments measuring STEM courses and careers (e.g. Tyler-Wood, Knezek & Christensen, 2010). The literature indicated the need for a survey instrument that was developed for middle school students (Tyler-Wood, Knezek & Christensen 2010; Usher, 2009).

Stage 2: Create a broad item pool of items that will test the target aspect

Initial survey items were developed that connected to each of the aspects of the social cognitive career theory. We were guided by our literature review, a middle school math and science self-efficacy scale (Fouad, Smith & Enoch, 1997), and eight separate classroom STEM career discussions with 6th-8th grade students at one of the participating schools in our development of the initial survey items with age-appropriate wording.

Table 2

Examples from a previous version of the survey

<table>
<thead>
<tr>
<th>Original Questions Numbers</th>
<th>SCCT Aspects Measured</th>
<th>Example Question</th>
<th>Original Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5</td>
<td>self-efficacy</td>
<td>I am able to get a good grade in science.</td>
<td>0.762</td>
</tr>
<tr>
<td>6-10</td>
<td>personal goals</td>
<td>I intend to enter a career that uses science.</td>
<td>0.679</td>
</tr>
<tr>
<td>11-15</td>
<td>outcome expectations</td>
<td>If I do well in my math classes, it will help me in my future careers.</td>
<td>0.672</td>
</tr>
<tr>
<td>16-20</td>
<td>Interest</td>
<td>I am interested in careers that use science.</td>
<td>0.613</td>
</tr>
<tr>
<td>21-25</td>
<td>personal inputs</td>
<td>I would feel comfortable talking to</td>
<td>0.604</td>
</tr>
</tbody>
</table>
From this, we developed a 30 item instrument with 5 statements per SCCT aspect statements: questions about self-efficacy for mathematics, science, and technology were grouped together, as were questions related to student interest, outcome expectancy, and the other measured factors (see Table 2 for examples of original items). These statements were reviewed by three science educators, one statistician in educational psychology, and a STEM career counseling professor to determine how many choices would be offered (5), if the questions were linked appropriately to all of the aspects of the social cognitive career theory, and whether the questions were understandable to middle school students. For the purpose of scoring and analyzing the STEM-CIS data, the response “strongly disagree” corresponded to a score of 1, “disagree” corresponded to 2, “neutral” corresponded to 3, “agree” corresponded to 4, and “strongly agree” corresponded to 5.

**Stage 3: Preliminary pilot testing of items**

These thirty survey items developed in Stage 2 were piloted with 61 students in an urban middle school, not a part of the larger study group, with 42.6% African American, 7.4% Hispanic, 38.6% White and American Indian 1.7% students, with 51.9% free-and-reduced lunch. Students took the survey on an iPod Touch, taking them approximately 10 minutes.

Structural analyses from this pilot study found poor correlation scores between items, and lower than anticipated alphas within each SCCT aspect. Several questions combined math and science into a single item. These questions in particular, as well as all questions addressing student barriers in math, science, and technology, had very low item correlations (ranging from
0.05 to 0.16). This led to the elimination of several questions due to an inability to determine whether students were thinking about math, science or both when answering the questions.

Examples of these questions included:

- It is too hard to get a career in math and science.
- If I get good grades in math and science, my parents will approve of me.

We hypothesized that total item correlations and alpha’s may be stronger if we restructured our survey into subject areas of science, math, and technology, eliminated questions regarding barriers, and added another question about being supported in these subject areas. This led to the organization of 11 questions that addressed six social cognitive career factors: self-efficacy (2), outcome expectations (2), goals (2), interests (2), contextual supports (2), and (1) personal disposition conducive to finding out more information about a career in the field. These items were piloted again with three middle schools. The demographics of these schools are summarized in Table 3.

Table 3

Demographics of pilot schools*

<table>
<thead>
<tr>
<th></th>
<th>Free and Reduced Lunch</th>
<th>African American</th>
<th>White</th>
<th>Hispanic</th>
<th>American Indian</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>School A</td>
<td>82.4</td>
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<td>12.9</td>
<td>1.9</td>
<td>0.9</td>
<td>1.1</td>
</tr>
<tr>
<td>School F</td>
<td>59.4</td>
<td>40.5</td>
<td>51.4</td>
<td>2.8</td>
<td>0.4</td>
<td>4.9</td>
</tr>
<tr>
<td>School H</td>
<td>51.9</td>
<td>42.6</td>
<td>38.6</td>
<td>7.4</td>
<td>1.7</td>
<td>9.7</td>
</tr>
</tbody>
</table>

Source: www.schooldigger.com – 2010-2011 school year. *All numbers are in percentages.

Stage 4: Conducting structural analysis to determine which items are to be eliminated from the pool of items

We were satisfied with the internal consistency estimates of the subscales (described below), but an initial confirmatory factor analysis led to a modification of two questions in the
technology subscale. We piloted those technology questions with the newly developed engineering scale, which was worded consistently with the other three subscales. These questions were piloted with 102 students from schools A, B, D, E, and G. The engineering scale alone was also piloted at school H, with 148 students. This totaled 250 students who took the engineering scale and 102 students who responded to the technology scale with the two revised items. These students also took the survey on an iPod Touch, in approximately 10 minutes. The many stages of piloting and revising the subscales explains the difference in sample sizes when doing the final measures of internal consistency and confirmatory factor analyses (Tables 4 and 5).

Table 4

Item correlations for STEM-CIS

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Alpha or item-total correlation</th>
<th>Social Cognitive Career Theory Aspect</th>
<th>Item*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>α = 0.77, average scale score = 27.61, SD = 7.19, N = 831</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>.42</td>
<td>Self-Efficacy</td>
<td>I am able to get a good grade in my science class.</td>
</tr>
<tr>
<td>S2</td>
<td>.47</td>
<td>Self-Efficacy</td>
<td>I am able to complete my science homework.</td>
</tr>
<tr>
<td>S3</td>
<td>.48</td>
<td>Personal Goal</td>
<td>I plan to use science in my future career.</td>
</tr>
<tr>
<td>S4</td>
<td>.48</td>
<td>Personal Goal</td>
<td>I will work hard in my science classes.</td>
</tr>
<tr>
<td>S5</td>
<td>.48</td>
<td>Outcome Expectation</td>
<td>If I do well in science classes, it will help me in my future career.</td>
</tr>
<tr>
<td>S6</td>
<td>.43</td>
<td>Interest in science</td>
<td>My parents would like it if I choose a science career.</td>
</tr>
<tr>
<td>S7</td>
<td>.43</td>
<td>Interest in science</td>
<td>I am interested in careers that use science.</td>
</tr>
<tr>
<td>S8</td>
<td>.49</td>
<td>Interest in science</td>
<td>I like my science class.</td>
</tr>
<tr>
<td>S9</td>
<td>.30</td>
<td>Contextual Support</td>
<td>I have a role model in a science career</td>
</tr>
<tr>
<td>S10</td>
<td>.44</td>
<td>Personal input</td>
<td>I would feel comfortable talking to people who work in science careers.</td>
</tr>
<tr>
<td>S11</td>
<td>.29</td>
<td>Contextual Support</td>
<td>I know of someone in my family who uses science in their career.</td>
</tr>
</tbody>
</table>

Mathematics α = 0.85, average scale score = 25.17, SD = 8.52, N = 829
<table>
<thead>
<tr>
<th>M1</th>
<th>.57</th>
<th>Self-Efficacy</th>
<th>I am able to get a good grade in my math class.</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2</td>
<td>.59</td>
<td>Self-Efficacy</td>
<td>I am able to complete my math homework.</td>
</tr>
<tr>
<td>M3</td>
<td>.60</td>
<td>Personal Goal</td>
<td>I plan to use math in my future career.</td>
</tr>
<tr>
<td>M4</td>
<td>.57</td>
<td>Personal Goal</td>
<td>I will work hard in my math classes.</td>
</tr>
<tr>
<td>M5</td>
<td>.62</td>
<td>Outcome Expectation</td>
<td>If I do well in math classes, it will help me in my future career.</td>
</tr>
<tr>
<td>M6</td>
<td>.43</td>
<td>Outcome Expectation</td>
<td>My parents would like it if I choose a math career.</td>
</tr>
<tr>
<td>M7</td>
<td>.52</td>
<td>Interest in math</td>
<td>I am interested in careers that use math.</td>
</tr>
<tr>
<td>M8</td>
<td>.57</td>
<td>Interest in math</td>
<td>I like my math class.</td>
</tr>
<tr>
<td>M9</td>
<td>.36</td>
<td>Contextual Support</td>
<td>I have a role model in a math career.</td>
</tr>
<tr>
<td>M10</td>
<td>.55</td>
<td>Personal Input</td>
<td>I would feel comfortable talking to people who work in math careers.</td>
</tr>
<tr>
<td>M11</td>
<td>.44</td>
<td>Contextual Support</td>
<td>I know someone in my family who uses math in their career.</td>
</tr>
</tbody>
</table>

**Technology**  
\( \alpha = 0.89, \text{ average scale score } = 26.27, \text{ SD } = 10.41, \text{ N } = 102 \)

<table>
<thead>
<tr>
<th>T1</th>
<th>.60</th>
<th>Self-Efficacy</th>
<th>I am able to do well in activities that involve technology.</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2</td>
<td>.38</td>
<td>Self-Efficacy</td>
<td>I am able to learn new technologies.</td>
</tr>
<tr>
<td>T3</td>
<td>.71</td>
<td>Personal Goal</td>
<td>I plan to use technology in my future career.</td>
</tr>
<tr>
<td>T4</td>
<td>.68</td>
<td>Personal Goal</td>
<td>I will learn about new technologies that will help me with school.</td>
</tr>
<tr>
<td>T5</td>
<td>.63</td>
<td>Outcome Expectation</td>
<td>If I learn a lot about technology, I will be able to do lots of different types of careers.</td>
</tr>
<tr>
<td>T6</td>
<td>.71</td>
<td>Outcome Expectation</td>
<td>When I use technology in school, I am able to get better grades.</td>
</tr>
<tr>
<td>T7</td>
<td>.68</td>
<td>Interest in technology</td>
<td>I like to use technology for class work.</td>
</tr>
<tr>
<td>T8</td>
<td>.57</td>
<td>Interest in technology</td>
<td>I am interested in careers that use technology.</td>
</tr>
<tr>
<td>T9</td>
<td>.59</td>
<td>Contextual Support</td>
<td>I have a role model who uses technology in their career.</td>
</tr>
<tr>
<td>T10</td>
<td>.55</td>
<td>Personal Input</td>
<td>I would feel comfortable talking to people who work in technology careers.</td>
</tr>
<tr>
<td>T11</td>
<td>.53</td>
<td>Contextual Support</td>
<td>I know of someone in my family who uses technology in their career.</td>
</tr>
</tbody>
</table>

**Engineering**  
\( \alpha = 0.86, \text{ average scale score } = 30.03, \text{ SD } = 8.85, \text{ N } = 250 \)

<p>| E1  | .59 | Self-Efficacy | I am able to do well in activities that involve engineering. |</p>
<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E2</td>
<td>.60</td>
<td>Self-Efficacy</td>
<td>I am able to complete activities that involve engineering.</td>
</tr>
<tr>
<td>E3</td>
<td>.61</td>
<td>Personal Goal</td>
<td>I plan to use engineering in my future career.</td>
</tr>
<tr>
<td>E4</td>
<td>.54</td>
<td>Personal Goal</td>
<td>I will work hard on activities at school that involve engineering.</td>
</tr>
<tr>
<td>E5</td>
<td>.59</td>
<td>Outcome Expectation</td>
<td>If I learn a lot about engineering, I will be able to do lots of different types of careers.</td>
</tr>
<tr>
<td>E6</td>
<td>.53</td>
<td>Outcome Expectation</td>
<td>My parents would like it if I choose an engineering career.</td>
</tr>
<tr>
<td>E7</td>
<td>.66</td>
<td>Interest in engineering</td>
<td>I am interested in careers that involve engineering.</td>
</tr>
<tr>
<td>E8</td>
<td>.62</td>
<td>Interest in engineering</td>
<td>I like activities that involve engineering.</td>
</tr>
<tr>
<td>E9</td>
<td>.45</td>
<td>Contextual supports</td>
<td>I have a role model in an engineering career.</td>
</tr>
<tr>
<td>E10</td>
<td>.59</td>
<td>Personal input</td>
<td>I would feel comfortable talking to people who are engineers.</td>
</tr>
<tr>
<td>E11</td>
<td>.36</td>
<td>Contextual support</td>
<td>I know of someone in my family who is an engineer.</td>
</tr>
</tbody>
</table>

*Item choices were on a Likert-type scale, 1 (strongly agree), 2 (agree), 3 (neither agree nor disagree), 4 (disagree) & 5 (strongly disagree).

**Stages 5 & 6: Confirmatory factor analysis of subscales**

To verify the psychometric properties of each subscale (i.e. whether each subscale was one-dimensional with desirable model fit), each content scale (science, mathematics, technology, and engineering) was subjected to confirmatory factor analysis via AMOS¹. For each analysis, a single-factor solution was modeled using data from cases with complete data on those items. Modification indices were examined to optimize the fit of the initial model. Any inter-item correlations that resulted in a modification index (MI) of 8.00 or greater (a conservative rule for model modification as 4.00 indicates a significant improvement to model fit) were modeled. This resulted in slightly different parameters estimated for each content scale. Once a model was specified appropriately, the full data were imported into the model. AMOS can utilize cases with

¹ AMOS is the structural equation modeling software produced by with IBM/SPSS.
partial information (i.e., does not require complete data for all cases, and as such does not delete cases with partial missing data from the analysis) and therefore all CFA analyses reported below are based on the full sample of N=1061.

Table 5

Summary of confirmatory factor analyses

<table>
<thead>
<tr>
<th></th>
<th>Parameters estimated</th>
<th>Df</th>
<th>Chi square</th>
<th>CMIN/df</th>
<th>NFI</th>
<th>CFI</th>
<th>RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Only (N=1061)</td>
<td>49</td>
<td>28</td>
<td>59.45</td>
<td>2.12</td>
<td>.97</td>
<td>.98</td>
<td>.033</td>
</tr>
<tr>
<td>Math only (N=1061)</td>
<td>49</td>
<td>28</td>
<td>55.78</td>
<td>1.99</td>
<td>.98</td>
<td>.99</td>
<td>.031</td>
</tr>
<tr>
<td>Technology Only (N=1056)</td>
<td>42</td>
<td>35</td>
<td>70.46</td>
<td>2.01</td>
<td>.97</td>
<td>.99</td>
<td>.031</td>
</tr>
<tr>
<td>Engineering Only (N=1061)</td>
<td>39</td>
<td>38</td>
<td>50.27</td>
<td>1.32</td>
<td>.95</td>
<td>.99</td>
<td>.017</td>
</tr>
<tr>
<td>All Four Factors (N=1061)</td>
<td>215</td>
<td>819</td>
<td>1745.92</td>
<td>2.13</td>
<td>.84</td>
<td>.91</td>
<td>.033</td>
</tr>
<tr>
<td>All Items on One Factor (N=1061)</td>
<td>285</td>
<td>749</td>
<td>1356.70</td>
<td>1.811</td>
<td>.88</td>
<td>.94</td>
<td>.028</td>
</tr>
</tbody>
</table>

Note: In all models, means and intercepts were estimated in order to allow AMOS to handle missing data appropriately. This led to higher numbers of parameters estimated than other models but utilized the entire N=1061 sample for each analysis. The exception is in the Technology subscale, where 5 cases with Mahalanobis’ D² were removed from the analysis.
Science Subscale

For the science subscale analyses, Mahalanobis $D^2$ was used to evaluate multivariate outliers\(^2\). In this scale, a reasonable cutoff for $D^2$ with 38 parameters estimated would have been 53.38. No outliers with a $D^2$ over 36 were observed. Testing model fit in confirmatory factor analyses (CFA) routinely involves evaluating and reporting multiple fit indices, as each one captures different aspects of model fit. The chi-square statistic is the first measure of how well a model fits the data; however, it is greatly influenced by sample size and thus is rarely found to be non-significant in samples sufficiently large to legitimately perform CFA within (Thompson & Daniel, 1996). Therefore, an appropriate model fit was assessed using the Root Mean Square Error (RMSEA), the comparative fit index (CFI), the normed fit index (NFI). Model fit is usually considered adequate when the following criteria are met: RMSEA should be less than 0.08, NFI should meet or exceed 0.90, and CFI should meet or exceed 0.95\(^3\) (Byne, 2010; Hu & Bentler, 1999; Marsh, Hau, & Wen, 2004). Model chi-squared generally only is used for comparing nested models, as

\(^2\) Mahalanobis $D^2$ is a common index of whether an individual score is aberrant within the multivariate distribution of scores; higher numbers indicate the score is farther from the center of the multivariate distribution. Guidelines for assessing Mahalanobis $D^2$ suggest that a reasonable cut-off score is a chi square value that would be significant at $p<.05$ for the number of df equal to the number of variables or parameters estimated in the model.

\(^3\) Note that Marsh et al., 2004 argue against strict cutoff scores or “golden rules” and thus these indices should be treated as the continuous variables they are, and interpreted in context.
it is determined both by sample size and goodness of fit, and CMIN/df is a commonly reported scaling of chi-square, divided by the degrees of freedom in the model. In general, for both of these indices smaller numbers are better, but there is no widely-accepted way to interpret them objectively.

In Table 5 and Figure 2 we summarize this model. As you can see in the table, the model fit was strong, indicating that this subscale indeed represents a single coherent factor. In Figure 2, you can see that standardized factor loadings ranged from 0.22 to 0.65. Correlations between error terms represent correlations between scale items, and are not generally interpreted substantively.

**Mathematics Subscale**

Analysis of the math subscale was equally positive. Mahalanobis D² was examined to evaluate multivariate outliers, and again no multivariate outliers were observed. The results of this analysis are presented in Table 5 and Figure 3. As you can see in Table 5, model fit for this scale was strong, exceeding all recommendations for NFI, CFI, RMSEA, indicating that this subscale indeed represents a single coherent factor. Further, as Figure 3 shows, standardized factor loadings were generally strong, ranging from 0.29 to 0.70.

![Figure 2. Confirmatory factor analysis for mathematics.](image-url)
Technology Subscale

Examination of Mahalanobis D^2 statistics for the technology scale indicated five cases in excess of 60, which subsequently were removed as excessive multivariate outliers, leaving us N=1056 individuals retained for analysis. The results of this analysis are presented in Table 5 and Figure 4. As you can see in Table 5, this model fits the data well, with fit indices indicating excellent fit. Standardized factor loadings, presented in Figure 4, ranged from 0.51 to 0.95, again indicating that this subscale represents a single coherent factor.

![Figure 3. Confirmatory factor analysis for technology.](image)

Engineering scale

Examination of Mahalanobis’ D^2 indicated that no outliers were observed, and thus all individuals were retained for analysis of the engineering subscale. This analysis is summarized in Table 5 and Figure 5. Model fit for this scale was strong despite the relatively small sample size (N = 282) and standardized factor loadings ranged from 0.33 to 0.78, indicating that this subscale represents a single coherent factor.

![Figure 4. Confirmatory factor analysis for engineering.](image)
Discussion

The *STEM Career Interest* Survey developed in this study was shown to be psychometrically sound for each of the subscales of science, technology, engineering, and mathematics. Because some researchers will be interested in student interest toward more than one of these content areas, we also explored how these four subscales worked together as a single measure. This is a reasonable approach as analyses showed those four latent subscale scores to be strongly correlated; correlations between latent factors ranged from $r = .72$ to $.82$. Thus, we estimated two other models: all four subscales in a single model as four separate but correlated factors, and all items from all four subscales characterized as one single factor.

Because of the complex sampling history of this project, large amounts of imputation would be undesirable. Thus, these models were estimated using all 1061 students but without imputing missing data. This has the desirable effect of not relying upon hundreds of imputed engineering scale scores, for example, but has the undesirable side effect of not allowing the model to be fit using modification indices, and thus the model fit for these last two models is probably lower than otherwise might be achieved. We also were not able to examine the data for outliers, again, which could harm model fit.

Table 5 shows reasonable model fit for the four-factor model. In particular, RMSEA indicates strong model fit, despite NFI and CFI falling slightly below norms for strong models (recall Marsh, 2004) argue that strict adherence to cutoff rules is not defensible). Thus, it is our conclusion that it is defensible to use this instrument in middle grades populations with all four subscales characterized by four separate sub scores.

For researchers who seek one single overall score from these four subscales (or from several of them), the evidence from the single-factor model that included all items from all four
scales loading on a single factor shows good model fit, with a RMSEA well below norms and CFI and NFI that are reasonably strong. This model fit is not only strong in its own right, it is significantly better than the four-subscale model ($\Delta X^2 = 389.22$, df $= 70$, $p < .00000000001$; $\Delta CFI = 0.03$, $\Delta NFI = 0.04$, and $\Delta RMSEA = 0.005$). This final analysis supports combining all items into a single overarching scale score, should researchers find that desirable (see Table 5).

Thus, it is possible to use this scale in a variety of ways, each defensible and supported by these analyses. It is defensible to use any of the four subscales individually, to use more than one (or even all four) together in a single instrument, calculating individual subscale scores for each content area, and it is also defensible to use more than one subscale and combine all items into a single overall score reflecting career interests in the STEM field overall.

Conclusions

The STEM-CIS was developed to measure the effects of strategies intended to promote the awareness of, interest in, and intent to pursue STEM careers with rural, minority, middle school students (Author, 2010). Its development thus addressed calls for an age appropriate measure (Gushue, 2006; Lent, Lopez, Lopez & Sheu, 2008) that is theoretically strong (Whitfield, Feller and Wood, 2008) With this particular population, we were interested in finding out not only if students were interested in STEM subjects and careers, but also what factors influenced this interest.

The development of this survey built on the previous instruments (Fouad, Smith, & Enoch, 1997; Tyler-Wood, Knezek and Chistensen, 2010), as well as a promising framework, the social cognitive career theory (Lent, Brown, & Hackett, 1994; 2000). The SCCT has been used and psychometrically evaluated in predicting interest with middle school students, and now has been applied to this new STEM career interest survey. Innovations worldwide depend on highly
qualified professionals in STEM careers (Hill, Corbett, & St. Rose, 2010; Regisford, 2012; White House Office of Science and Technology Policy, 2012).

Implications

The STEM Career Interest Survey developed in this study was shown to be psychometrically sound and able to be used by researchers or professional developers in science, technology, engineering, and mathematics, using one or more subscales or all of them as one instrument, as needed. As such, we expect it will be beneficial to researchers, professional developers, and evaluators in measuring STEM Career interest and the effects of STEM programs on changes in student interest in STEM subjects and careers. The knowledge we gain from the use of this instrument may help to inform efforts taken at the middle school level as we seek to increase students’ interest in STEM subjects, majors, and careers. We also plan to validate this instrument with other populations of students in urban settings and at the high school level.

References


Appendix A: STEM Career Interest Survey (STEM-CIS)

Optional Demographic Questions

1. Date
2. First name
3. Last name
4. Grade
5. Gender
6. Teacher
7. Race
8. Period
9. School

Directions: Students will complete the STEM-CIS online via iPod Touches or computers. Each question is Likert scale with the following choices:

Strongly Disagree (1), Disagree (2), Neither Agree nor Disagree (3), Agree (4), Strongly Agree (5)

Science

S1  I am able to get a good grade in my science class.

S2  I am able to complete my science homework.
I plan to use science in my future career.

I will work hard in my science classes.

If I do well in science classes, it will help me in my future career.

My parents would like it if I choose a science career.

I am interested in careers that use science.

I like my science class.

I have a role model in a science career.

I would feel comfortable talking to people who work in science careers.

I know of someone in my family who uses science in their career.

I am able to get a good grade in my math class.

I am able to complete my math homework.

I plan to use math in my future career.

I will work hard in my math classes.

If I do well in math classes, it will help me in my future career.

My parents would like it if I choose a math career.

I am interested in careers that use math.

I like my math class.

I have a role model in a math career.

I would feel comfortable talking to people who work in math careers.

I know someone in my family who uses math in their career.

I am able to do well in activities that involve technology.
T2 I am able to learn new technologies.
T3 I plan to use technology in my future career.
T4 I will learn about new technologies that will help me with school.
T5 If I learn a lot about technology, I will be able to do lots of different types of careers.
T6 My parents would like it if I choose a technology career.
T7 I like to use technology for class work.
T8 I am interested in careers that use technology.
T9 I have a role model who uses technology in their career.
T10 I would feel comfortable talking to people who work in technology careers.
T11 I know of someone in my family who uses technology in their career.

Engineering

E1 I am able to do well in activities that involve engineering.
E2 I am able to complete activities that involve engineering.
E3 I plan to use engineering in my future career.
E4 I will work hard on activities at school that involve engineering.
E5 If I learn a lot about engineering, I will be able to do lots of different types of careers.
E6 My parents would like it if I choose an engineering career.
E7 I am interested in careers that involve engineering.
E8 I like activities that involve engineering.
E9 I have a role model in an engineering career.
E10 I would feel comfortable talking to people who are engineers.
I know of someone in my family who is an engineer.