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Student Attitudes Toward STEM: A Revised Instrument of Social Cognitive Career Theory Constructs (Fundamental)

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Student Attitudes Toward STEM: A Revised Instrument of Social Cognitive Career Theory Constructs

Literature indicates students in the K-12 setting are underperforming in STEM subjects (American College Testing, 2013; National Science Board, 2012) and demonstrate a lack of interest in STEM fields (Institute of Medicine, National Academy of Science, & National Academy of Engineering, 2007). This is particularly concerning given STEM-related career opportunities will grow considerably over the next decade (Carnevale, Smith, & Stroh, 2010) and interest in STEM fields insufficiently meets U.S. imminent workforce demands (National Science Board, 2015). The President's Council of Advisors on Science and Technology (PCAST, 2012) project that in order to retain its historical preeminence in science and technology, the U.S. will need approximately one million more STEM professionals than it will produce over the next decade. To accomplish this goal, a 34 percent annual increase in the number of students who receive undergraduate STEM degrees is needed (PCAST, 2012). Despite this need, only 24 percent of incoming college students declare a STEM major (Shapiro & Sax, 2011) and less than half of the students who declare a STEM major graduate with a STEM degree (Price, 2010). Furthermore, the U.S. ranks 17th amongst developed countries in the proportion of college students receiving bachelor's degrees in science and engineering (National Academy Press, 2007). Therefore, increasing STEM degree completion in the U.S. has been identified as an issue of national priority to boost global competiveness (National Governors Association, 2011).

This national need may be met by encouraging students to enter STEM fields and then retaining these individuals as they progress through careers (Heilbronner, 2011). To do so, researchers need to understand the factors that influence student STEM career interest and learning. For many students, high school academic preparation plays a critical role in the decision to study STEM in college (Green and Saderson, 2014; Harris Interactive, 2011; Moakler & Kim, 2014; Tyson, Lee, Borman, & Hanson, 2007; Wang, 2013). Harris Interactive (2011) found that nearly four in five STEM college students (78%) say that they decided to study STEM in high school or earlier. This indicates that more focus is needed to determine the factors involved in pursuing (or not pursuing) a STEM major in pre-college education.

A framework that has been utilized to study academic and career development in recent years is social cognitive career theory (SCCT; Lent & Brown, 2006, 2008; Lent, Brown, & Hacket, 1994, 2000). One major thread of research on SCCT has focused on the pursuit (or avoidance) of science, technology, engineering, and mathematics (STEM) related coursework and academic majors (Lent, Sheu, Singley, Schmidt, Schmidt, & Gloster, 2008). Findings indicate that individual components of SCCT are good predictors of academic achievement and persistence in STEM fields (Lent, Brown, & Larken, 1984; Nugent, Barker, Welch, Grandgenett, Wu, & Nelson; 2015). In this paper we discuss the development of the Student Interest and Choice in STEM (SIC-STEM) Survey, an instrument designed to measure components of SCCT that interplay in students' lives and impact their decision to pursue (or not pursue) a STEM career. We also share pilot data used for validating the instrument.

Theoretical framework

SCCT is an approach to understand educational and occupational behavior (Lent, 2013), by providing a sequential framework that models the processes by which students choose and persist in a particular major and career (Lent et al., 1994). It is mainly derived from Bandura's (1986) social cognitive theory, which explores the way people, their behavior, and their environments influence one another (Lent, 2013). The SCCT framework acknowledges the capacity for individuals to direct their own vocational behavior while also recognizing personal and environmental influences that may strengthen, weaken, or negate self-direction in career development (Lent, 2013). The SCCT framework explores four interrelated aspects of career development: (1) how basic academic and career interests develop, (2) how educational and career choices are made, (3) how academic and career success is obtained, and (4) how satisfaction or well-being in the work environment is experienced (Lent, 2013). Respectively, the SCCT framework is divided into four compartmentalized yet interrelated models including *interest, choice, performance* (Lent, et al., 1994)*,* and *satisfaction* (Lent, 2013). Within each model of SCCT are three sociocognitive mechanisms—self-efficacy beliefs, outcome expectations, and personal goals— that are believed to exert important influences to career development (Lent, et al., 1994). The next paragraphs will discuss each of these mechanisms, followed by a more detailed description of the interest and choice models within the SCCT framework.

Self-efficacy, outcome expectations, and personal goals

Developed by Bandura (1986), self-efficacy is defined as an individual's belief of his/her ability to perform a certain behavior. Self-efficacy is believed to be influenced by four corresponding, career-relevant learning experiences including personal performance accomplishments, vicarious learning (e.g., observing similar others), social persuasion, and physiological and affective states (Bandura, 1997). SCCT assumes that individuals are likely to develop interests, choose to pursue, and perform better at activities at which they have strong self-efficacy beliefs (Lent, 2013).

Outcome expectations refer to an individual's beliefs about the consequences or outcomes of performing particular behaviors (Lent, 2005; 2013). Bandura suggested that self-efficacy and outcome expectations help determine whether an individual will choose to pursue or avoid an activity. For example, people are more likely to engage in an activity that they view as leading to valued or positive outcomes (e.g., social and self-approval, tangible rewards, desirable work conditions) (Bandura, 1986; Lent et al, 1994; Lent, 2013). Self-efficacy is believed to affect outcome expectations, especially in situations where the outcome is closely related to the quality of an individual's performance (Lent, 2013).

Personal goals are described as one's intention to engage in a particular activity or produce a particular outcome (Bandura, 1986). SCCT describes two types of personal goals referred to as choice goals (the type of activity or career one wishes to pursue) and performance goals (the quality of performance one plans to achieve within a given task; Lent, 2013). SCCT suggests that both choice and performance goals are affected by an individual's self-efficacy and outcome expectations.

Interest and choice models of the SCCT framework

While SCCT consists of four conceptually distinct, yet overlapping models, the researchers decided to focus building an instrument around the interest and choice models. This decision was made because students could be asked general, selected-response questions to report about their interest and potential choices. However, more student-specific and extended-response items would have been necessary to investigate students' performance and satisfaction. The following paragraphs will discuss the interest and choice models, as well as provide examples of how the three mechanisms within the model may drive a student's career decision.

The *interest* model focuses on how individuals develop career and educational interests. According to SCCT, interests in activities will develop when individuals view themselves as competent in the activity (self-efficacy) and they anticipate positive outcomes after performing the activity (Lent, 2013). Once interests emerge, a feedback loop with self-efficacy and outcome expectations is developed. For example, if an individual is exposed to playing the piano, and has received positive feedback on her ability to play the piano, she is likely to develop a high self-efficacy for piano playing. If she views that playing the piano will demonstrate a positive outcome in her future, her high self-efficacy combined with her outcome expectation will likely blossom her interest in playing the piano. This interest, self-efficacy, and outcome expectations are likely to encourage her personal goals for increasing her involvement for playing the piano, which in turn, increases her likelihood to actively practice, which will likely refine her self-efficacy and outcome expectations (Lent, 2013). Whether interests change or solidify is determined by restriction or further exposure to compelling learning experiences that are related to the activity in hand (Lent, 2013).

The *choice* model focuses on the formation of educational and career choices and consists of (1) expression of career choice, (2) actions designed to implement this choice, and (3) subsequent performance experiences that form a feedback loop that affects the shape of an individual's choice options (Lent et al., 1994). Self-efficacy and outcome expectations influence career-related interests, which tend to foster career choice goals (i.e., intentions to pursue a particular career path). Choice goals motivate choice actions, or efforts to implement one's goals such as seeking additional training (Lent, 2013). For example, after gaining entry into medical school, a student may have difficulty completing the required coursework. He may also conclude that the work conditions and rewards available as a medical doctor suit him less well than he initially anticipated. These learning experiences may incite the student to revise his self-efficacy beliefs and outcome expectations, leading to a shift in interest and goals (selection of a new career path).

Other instruments based on SCCT

While there are instruments that measure student outcomes (content knowledge, reasoning skills, psychosocial attributes) after participating in various disciplines of STEM fields (Minner, Ericson, Wu, & Martinez, 2012; Romine, Sadler, Presley, & Klosterman, 2012), there have been few that systematically gather the information across all STEM subject areas (Erkut & Marx, 2005; Tyler-Wood, Knezek, & Christensen, 2010). There have been two surveys that have utilized the SCCT framework in their development: the Student Attitudes toward STEM (S-STEM; Unfried, Faber, Stanhope, & Wiebe, 2015) and the STEM Career Interest Survey (STEM-CIS; Kier, Blanchard, Osborne, & Albert, 2013). The S-STEM (Unfried et al., 2015) measures student attitudes in STEM and interests in STEM careers. However, it does not separate the various socio-cognitive mechanisms of self-efficacy, outcome expectations, and personal goals. The STEM-CIS (Kier et al., 2013) measures student interest in STEM fields; the survey connects the three socio-cognitive mechanisms (self-efficacy, outcome expectations, and personal goals) with two questions for each discipline in STEM. Additionally, it examines how contextual influences (i.e. supports and barrier that may facilitate or hinder one's ability to make a particular choice) may influence a student's interest in STEM. Despite this, neither survey examines the choice actions that may guide a student to follow a certain career path, as outlined in the SCCT framework.

Instrument development

The creation of the SIC-STEM Survey began from an investigation of Faber, Wiebe, Corn, Townsend, and Collins' (2013) S-STEM instrument. We intentionally selected the S-STEM instrument due to its alignment with SCCT and also because there were similar teacher surveys that could be utilized for our larger study about students' STEM perceptions and barriers (i.e. T-STEM). Adhering to the SCCT framework, we operationalized Lent's (2013) SCCT construct definitions to create working definitions that we could use for item coding and construction (Figure 1).

SCCT Construct	Working Definition	Item Examples
Self-efficacy	Items focus on one's perceived ability or a judgment of one's ability. For example, "I can do something" or "I am good/bad at something."	• I believe I can be successful in engineering. • I am the type of student who does well in math.
Outcome Expectations	Items focus on the cause (decision or action) and effect (consequence of that decision). For example, "If I do this, then this will happen."	• When I am older, knowing science will help me earn money. • If I learn engineering, then I can improve things that people use every day.
Interests	Items focus on whether students either like or do not like something. For example, "I like/do not like something."	• I like math. • I enjoy doing science work.
Choice Goals	Items focus on a goal or "wanting to do something" that was aligned to a STEM activity or career.	• Designing products or structures will be important in my future job. • Someday I want to do a job that uses math.

Choice Actions	Items need to 1) reference a career/job and 2) include a statement about taking an action. For example, "I work on problem solving skills in math club because I want a math job someday" implies that the decision to work on problem solving skills (an action) is viewed as being supportive toward getting a math job (future career goal).	• I go to science club because I know understanding science will be important for my future career. • I use computers because I know I will need those skills in my future job.

Figure 1. SCCT construct working definitions for item coding and construction.

Item development

Four researchers with specialties in math, science, or engineering/technology mapped the S-STEM items to the five SCCT constructs. The initial coding of items between the four researchers demonstrated 86% inter-rater reliability. Items that demonstrated disagreement were discussed until total agreement was reached on each item between the four researchers. The map identified that the S-STEM items were not evenly distributed across the SCCT constructs and in some cases were lacking entirely. There were math, science, and engineering & technology items that measured self-efficacy and career goals, but none that addressed career actions. Furthermore, interest items were only coded for engineering & technology.

Since the items were not evenly distributed across the SCCT constructs, we created the SIC-STEM Survey to measure students' STEM attitudes using all five SCCT constructs (self-efficacy, outcome expectations, interests, choice goals, and choice actions). The revised instrument maintains the three categories (math, science, and engineering & technology) and the 5-point Likert-type response scale (strongly disagree to strongly agree). In order to more evenly distribute items across the categories and maintain a reasonable survey length for students, we adopted the suggested minimum of three questions for measuring a construct (DeVellis, 1991). Therefore, each of the categories contained three questions for each SCCT construct. This resulted in 15 items per category, and 45 items total (Appendix).

Descriptive statistic of the sample

The SIC-STEM Survey was administered online with Survey Monkey at 12 high schools across the United States (Figure 2). A total of 196 out of 210 students completed the survey within physics or engineering classes where the students were participating in a STEM outreach project. The high schools were located in four different states, ranging from northern to southeastern states, and varied in school size (125-1,500 enrolled students). Out of the 12 schools, 9 were predominately White with Hispanic or Black being the top minorities, and 3 were almost entirely Hispanic. The cities in which the schools were located are described as lower and middle class with less and moderately educated populations. Data about gender and ethnicity were not collected on this survey; however, the overall population contained 76 female students and 134 male students.

High School	Location	Number of Students Surveyed	Total Students in Class	Type of Class	Male	Female
BHS	Central Southern U.S.	12	14	Engineering	4	10
CHS	Central Southern U.S.	45	45	Engineering	25	20
DHS	Southern U.S.	15	15	Physics	7	8
GHS	Northern U.S.	16	16	Physics	9	7
JHS	Southern U.S.	14	14	Engineering	13	1
KHS	Southern U.S.	20	20	Physics	14	6
LHS	East Southeastern U.S.	5	6	Engineering	3	3
MHS	Central Southern U.S.	15	16	Engineering	7	9
NHS	Central Southern U.S.	9	9	Extra-Curricular	6	3
PHS	Southern U.S.	13	13	Engineering	13	0
RHS	Southern U.S.	21	31	Engineering	24	7
THS	Northern U.S.	11	11	Physics	9	2
Total		**196**	**210**		**134**	**76**

Figure 2. Demographics of the surveyed population.

Limitations

A limitation of this study is that all students surveyed are participants of a STEM class. In other words, the students enrolled in these classes have the potential to be interested in STEM. Another limitation is the lack of a specific process for presenting the survey to the students. For example, when the survey was distributed there was no prescribed procedure given to the teachers of when and how the survey would be introduced. Therefore, each teacher could have administered the survey slightly differently.

Analysis

After coding and inputting the SIC-STEM Survey data (N=196), the 45 items on the instrument were subjected to principal component analysis (PCA) using SPSS 9.5 Version 22. Prior to performing PCA the suitability of data factor analysis was assessed. We used a confirmatory factor analysis (CFA) to confirm or reject the measurement theory and to test whether the hypothesized latent constructs were appropriate for future multivariate data analysis (Fox, 2010).

Inspection of the correlation matrix revealed the presence of several coefficients of 0.3 and above. The Kaiser-Meyer-Olkin value was 0.910, exceeding the recommended value of 0.6 (Kaiser, 1958, 1970). PCA revealed the presence of nine components with eigenvalues exceeding 1.0, explaining 34.1 percent, 9.4 percent, 7.4 percent, 5.8 percent, 3.6 percent, 2.8 percent, 2.7 percent, 2.4 percent, 2.2 percent respectively. These nine components explained a total of 70.8 percent of the total variance. Further inspection of the data was conducted using a scree plot analysis, which revealed a clear break after the fifth component (See Figure 3). Using Cattell’s (1966) scree test, it was decided to retain five components for investigation of reliability.

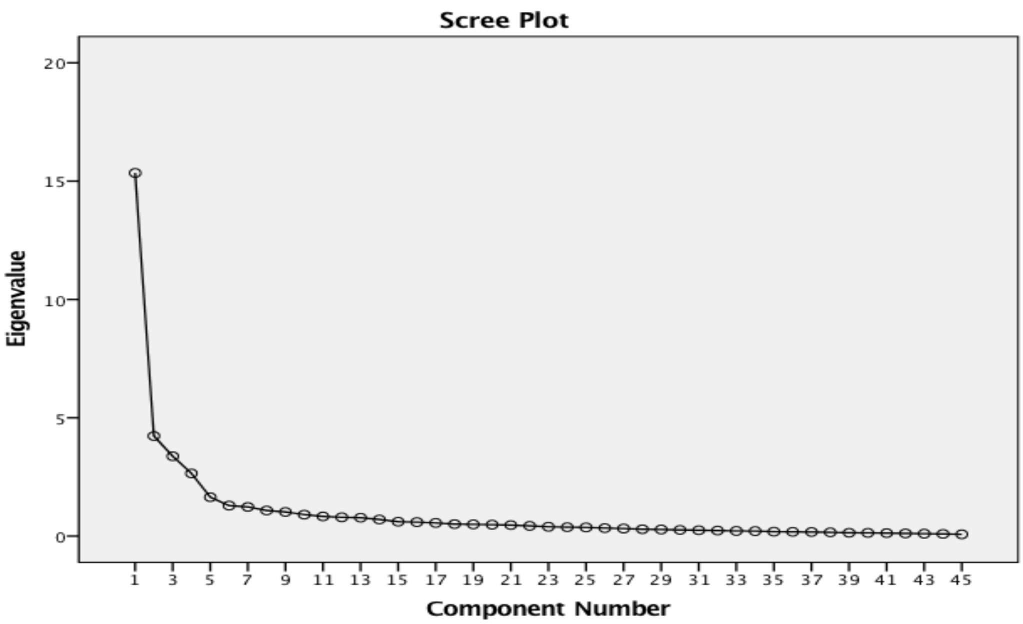

Figure 3. Scree plot indicating the proportion of variance for each of the principal components.

Using 0.7 as an acceptable reliability coefficient (Cronbach, 1951; Nunnally, 1978), we measured the internal consistency reliability for the instrument as a whole, the content specific subscales, and the latent constructs within each of the subscales. These values were calculated using the entire sample of data for each survey. All constructs demonstrated sufficient levels of reliability.

Reliability for the overall instrument revealed a Cronbach's alpha of 0.951. The math subscale revealed a Cronbach's alpha of 0.916, the science subscale revealed a Cronbach's alpha of 0.921, and the engineering/technology subscale revealed a Cronbach's alpha 0.916. To further assess the internal consistency, reliability measures were calculated for each of the latent constructs within each of the content specific areas. There were three items that represented each of the intended latent constructs; therefore, we also paid attention to the Cronbach's alphas of "if deleted" items within each of those constructs. (See Table 1-Table 3).

Table 1.
Mathematics Psychometric Data (N=196)

Variable	Cronbach's alpha	Cronbach's alpha if deleted		
Interest	0.797	M1 (0.898)	M6 (0.581)	M11 (0.619)
Self-Efficacy	0.823	M2 (0.761)	M7 (0.623)	M12 (0.849)
Outcome Expectations	0.140*	M3 (0.125)*	M8 (0.296)*	M13 (-0.147)*
Choice Goal	0.887	M4 (0.824)	M9 (0.924)	M14 (0.762)
Choice Action	0.799	M5 (0.731)	M10 (0.634)	M15 (0.796)
Total Math Subscale	0.916			

Note. * indicates criteria that were reviewed and revised

Table 2.
Science Psychometric Data (N=196)

Variable	Cronbach's alpha	Cronbach's alpha if deleted		
Interest	0.754	S1 (0.529)	S6 (0.682)	S11 (0.779)
Self-Efficacy	0.688*	S2 (0.532)	S7 (0.557)	S12 (0.703)*
Outcome Expectations	0.600*	S3 (0.210)	S8 (0.355)	S13 (0.849)*
Choice Goal	0.906	S4 (0.853)	S9 (0.879)	S14 (0.863)
Choice Action	0.846	S5 (0.718)	S10 (0.898)	S15 (0.715)
Total Science Subscale	0.921			

Note. * indicates criteria that were reviewed and revised

Table 3.
Engineering and Technology Psychometric Data (N=196)

Variable	Cronbach's alpha	Cronbach's alpha if deleted		
Interest	0.722	ET1 (0.746)	ET6 (0.694)	ET11 (0.431)
Self-Efficacy	0.636*	ET2 (0.652)*	ET7 (0.303)	ET12 (0.609)*
Outcome Expectations	0.685*	ET3 (0.504)	ET8 (0.603)	ET13 (0.696)*
Choice Goal	0.774	ET4 (0.607)	ET9 (0.804)	ET14 (0.627)
Choice Action	0.631*	ET5 (0.573)	ET10 (0.382)	ET15 (0.614)*
Total E&T Subscale	0.916			

Note. * indicates criteria that were reviewed and revised

Specific items within each of the subscales that revealed Cronbach's alpha scores below a 0.7 were revaluated, discussed among content expert researchers, and re-worded to better represent the construct as operationally defined.

Conclusion/Future directions

In an effort to help address the national need for more STEM graduates, we created the SIC-STEM Survey as a data collection instrument that had the potential to provide insight into the factors that influence student STEM career interest. The SIC-STEM Survey was intentionally designed with alignment to the SCCT interest and choice models, and specifically takes five constructs (interest, self-efficacy, outcome expectations, choice goal, and choice actions) into consideration. To our knowledge, the SIC-STEM Survey is the first student survey to attempt to collect data about choice goals and choice actions.

Our thoughts in the development of this survey are to provide individual schools with data that can be utilized to aid administrators in revamping their current curriculum. The data could be used to begin thinking about new ways to provide students with opportunities for building their self-efficacy and/or interest in math, science, technology and engineering. Further, by finding ways to increase student self-efficacy and/or interest our hope is that students will be encouraged to enter STEM fields in college and persist through to obtaining a STEM career.

Data from the initial pilot of the SIC-STEM Survey demonstrates some evidence for the validity of the items and reliability of the instrument. In an effort to further improve item validity and instrument reliability, we investigated constructs yielding a less than satisfactory Cronbach's alpha below 0.7 (Nunnally, 1978). We investigated and revised the items that may have contributed to the lower Cronbach's alpha. These new items will be tested for reliability and validity in a second pilot with another sample of high school students.

Furthermore, while investigating which items might be revised to increase the Cronbach's alpha for each construct, we noticed that many of these were reversed items. In fact, two out of three of the reversed items in each category, or six out of nine in the instrument, indicated the Cronbach's alpha for that construct would be increased if the item were removed. We originally included the reversed items in an effort to see if the students were paying attention when completing the survey, but also wonder if the negative language in the item is interfering with more reliable results. In addition to revising items that yield Cronbach alpha's below 0.7, we also reviewed the readability of various items within the instrument. We noticed that several items might have caused students to answer in a particular way because the readability may have been too high. Therefore, items were simplified and recoded to ensure that items still matched the coding categories. This resulted in a new readability at the fifth-grade level. At this time, the reversed items and the simplified items will be used in a second pilot to determine their effect on the reliability and validity of the instrument. Once we receive high-levels of reliability and validity from the piloted data, the instrument can be used in school systems to inform stakeholders of students' interests and choices toward STEM. Moreover, the data obtained from school systems can also be used to help begin discussions to revitalize better STEM opportunities for students.

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Appendix

The Student Interest and Choice in STEM (SIC-STEM) Survey Items

MATH

		Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1.	I don’t like playing math games.	☐	☐	☐	☐	☐
2.	Math is hard for me.	☐	☐	☐	☐	☐
3.	If I join a math club, I will become better at math.	☐	☐	☐	☐	☐
4.	When I’m older, I might choose a job that uses math.	☐	☐	☐	☐	☐
5.	I work on problem solving skills in math club because I want a math job someday.	☐	☐	☐	☐	☐
6.	I like math.	☐	☐	☐	☐	☐
7.	I am the type of student who does well in math.	☐	☐	☐	☐	☐
8.	When I try hard, I still cannot solve math problems.	☐	☐	☐	☐	☐
9.	In the future, I want to do harder math problems.	☐	☐	☐	☐	☐
10.	I try to do my best on math tests because I have an interest in math jobs.	☐	☐	☐	☐	☐
11.	I find math interesting.	☐	☐	☐	☐	☐
12.	I can get good grades in math.	☐	☐	☐	☐	☐
13.	Being able to do math will help me solve real-world problems.	☐	☐	☐	☐	☐
14.	Someday I want to do a job that uses math.	☐	☐	☐	☐	☐
15.	I ask a friend for help when I do not understand math problems because I know understanding math will be important in my future career.	☐	☐	☐	☐	☐

SCIENCE

		Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1.	I enjoy doing science work.	☐	☐	☐	☐	☐
2.	I feel good about myself when I do science.	☐	☐	☐	☐	☐
3.	When I am older, knowing science will help me earn money.	☐	☐	☐	☐	☐
4.	I might choose a job in science.	☐	☐	☐	☐	☐
5.	I do activities (Science Olympiad and science fair) because I want a science job someday.	☐	☐	☐	☐	☐
6.	I do not like science.	☐	☐	☐	☐	☐
7.	I know I can do well in science.	☐	☐	☐	☐	☐
8.	Learning science will help me get a good job.	☐	☐	☐	☐	☐
9.	After I finish high school, I will use science often.	☐	☐	☐	☐	☐
10.	I try to get an A or B in science because I have an interest in science jobs.	☐	☐	☐	☐	☐
11.	I like doing experiments to answer questions.	☐	☐	☐	☐	☐
12.	Science is hard for me.	☐	☐	☐	☐	☐
13.	Being able to do science will not help me solve real world problems.	☐	☐	☐	☐	☐
14.	Science will be important to me in my future career.	☐	☐	☐	☐	☐
15.	I go to science club because I know understanding science will be important for my future career.	☐	☐	☐	☐	☐

ENGINEERING AND TECHNOLOGY

Please read this paragraph before you answer the questions.

Engineers use math and science to invent things and solve problems. Engineers design and improve things like bridges, cars, machines, foods, and computer games. **Technologists** build, test, and maintain (or take care of) the designs that engineers create.

		Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1.	I like to imagine making new products.	☐	☐	☐	☐	☐
2.	I am bad at building or fixing things.	☐	☐	☐	☐	☐
3.	If I learn engineering, then I can improve things that people use every day.	☐	☐	☐	☐	☐
4.	Designing products or structures will be important in my future jobs.	☐	☐	☐	☐	☐
5.	I use computers because I know I will need those skills in my future job.	☐	☐	☐	☐	☐
6.	I am not interested in what makes machines work.	☐	☐	☐	☐	☐
7.	I believe I can be successful in engineering.	☐	☐	☐	☐	☐
8.	Knowing how to use math and science together will help me to invent useful things.	☐	☐	☐	☐	☐
9.	I want to be creative in my future jobs.	☐	☐	☐	☐	☐
10.	The skills I learn while building projects (bridges, cars, robots) will help me in my future job.	☐	☐	☐	☐	☐
11.	I am curious about how electronics work.	☐	☐	☐	☐	☐
12.	I believe that I can use math and science to solve problems.	☐	☐	☐	☐	☐
13.	Understanding engineering is not important for my career.	☐	☐	☐	☐	☐
14.	I would like to take more engineering/technology classes.	☐	☐	☐	☐	☐
15.	I ask my teacher for extra math and science practice to improve my problem solving skills for my future job.	☐	☐	☐	☐	☐