Validated Student, Teacher, and Principal Survey Instruments for STEM Education Programs

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Abstract

This paper discusses three survey instruments that can be used to measure outcomes of STEM education programs, including: student attitudes toward STEM and interest in STEM careers; teacher efficacy and beliefs for teaching STEM and use of STEM instructional practices; and principal leadership for STEM. The presentation will summarize the content of each survey and provide details regarding the reliability and validity testing that has been completed for each instrument. The paper shares descriptions of how these surveys have been used in three kindergarten-through-12th-grade STEM education evaluations: evaluation and capacity-building for data-driven decision-making in North Carolina State University's STEM outreach programs; a 14-grant cluster evaluation impacting over 200 elementary, middle, and high schools; and evaluation and capacity-building for district-wide STEM schools. Lastly, the paper will discuss practical considerations for evaluators using the instruments, including issues related to program size and goals, administration, and analysis methods.

Introduction

Sustaining a healthy, globally competitive US economy depends on attracting qualified students into STEM or STEM-allied careers (NAS, 2007). Research findings suggest kindergarten through 12th grade (K12) students' attitudes toward STEM subjects and interest in STEM careers affect the likelihood that students will participate in the STEM workforce (PCAST, 2010). A robust body of researchers has identified that teachers are the most important in-school factor impacting student learning; therefore teacher self-efficacy and beliefs regarding their subject matter are important components of any successful education program. Finally principals also have been found to be a critical factor in education program success; Cuban (2001), for example, found that science and technology curricular reforms may be short-lived due to a lack of professional development provided for principals. These patterns suggest the importance of understanding multiple perspectives – student, teacher, and principal – when evaluating K12 STEM education programs.

Our team of researchers at The Friday Institute for Educational Innovation at North Carolina State University has developed a set of survey instruments to assist in this endeavor. These include: the Student Attitudes toward STEM Survey (S-STEM; two versions, one for 4th and 5th grade students and one for 6th through 12th grade students); the Teacher Efficacy and Attitudes toward STEM Survey (T-STEM; five versions for mathematics teachers, science teachers, engineering teachers, technology teachers, and elementary school teachers); and the Principal Leadership for STEM Survey (P-STEM). This paper will discuss the content and psychometric properties of these three instruments, give examples of how these instruments have been used in various types of programs and evaluations, and share lessons learned in survey implementation and analysis.

Survey Content and Psychometric Properties

S-STEM Survey

<u>Survey Content</u>

The S-STEM survey measures student attitudes toward STEM and interest in STEM careers. Two versions of the survey exist to account for varying reading levels of students. One version is for upper elementary students (4th and 5th grade) and one is for middle/high school students (6th through 12th grade). The two versions remain entirely parallel in structure, but differ in specific wording in order to be appropriate for each reading-level. Each survey contains 37 attitudes items and 12 career-interest items.

The S-STEM Survey contains three constructs measuring attitudes toward STEM content and one measuring attitudes toward 21st century skills, all on a five-point Likert scale (*Strongly Disagree* to *Strongly Agree*). The three STEM content constructs measure attitudes toward science, mathematics, and engineering/technology. Engineering and technology are combined, treating technology as an inherent aspect of engineering. These STEM attitudes constructs were developed based on a survey for female, middle-school students in an engineering program (Erkut & Marx, 2005). The 21st century skills construct was adapted from a Student Learning

Conditions Survey (Friday Institute, 2010a). For these surveys, we defined a measure of attitudes as a combination of self-efficacy and expectancy-value measures. Self-efficacy is a student's belief in his or her ability to complete tasks or influence events that will impact his or her life (Bandura, 1986). Expectancy-value is the belief that attaining a certain goal will be valuable for a student's future. The STEM attitudes constructs, therefore, measure both self-efficacy and expectancy-value. The 21st century skills portion only measures self-efficacy since 21st century skills are general tasks that are taught in connection to particular subject-areas, and therefore task values would be confounded. An example of an item measuring self-efficacy from the attitudes toward mathematics construct is, "I am the type of student to do well in mathematics," whereas an expectancy-value item reads, "I would consider choosing a career that uses mathematics."

In addition to the four attitudes constructs, a survey section measures student interest in 12 STEM career pathways, using a four-point scale (*Not So Interested* to *Very Interested*). These items were developed from an exhaustive list of STEM careers found in the Occupational Outlook Handbook (Bureau of Labor Statistics, 2011). Each item defines the particular career pathway and gives examples of related occupations. An example career item is, "Engineering involves designing, testing, and manufacturing new products (like machines, bridges, buildings, and electronics) through the use of mathematics, science, and computers *(civil, industrial, agricultural, or mechanical engineers, welder, auto-mechanic, engineering technician, construction manager)*."

The survey also asks students: how well they expect to do in their English, mathematics, and science classes; if they plan to take advanced mathematics or science classes in the future; what their plans are for college; and if they know any adults who work in STEM fields.

Psychometric Properties

After the pilot survey was developed and edited, the S-STEM Survey was analyzed using two cohorts of data from 2011 and 2012. These 17,485 middle/high students and 4,232 upper elementary students attended schools that were implementing STEM education programs. The first year of data was used for exploratory factor analysis, and the second year of data was used for confirmatory factor analysis and measurement invariance. Data from both years were used to calculate reliability levels.

We used exploratory factor analysis with promax rotation, allowing for correlated factors, and classified loadings above .30 as significant. For each survey version, the results showed a clear four-factor structure for the attitudes items. (Career items were not analyzed in factor analysis, because they were not expected to form a construct.) Confirmatory factor analysis was performed on the second year of data. We fixed factor variances at 1 for identification, and used maximum likelihood estimation. The model allowed for four correlated attitudes factors. Further, within each of the three STEM attitudes factors, we allowed correlated residuals among the self-efficacy items and also among the expectancy-value items. This allowed us to account for systematic error that was not covered by the general attitudes factor. Due to the large sample size, survey fit was analyzed using alternative fit indices like SRMR, RMSEA, and CFI rather than by using χ^2. A good fit is generally indicated by SRMR < .08, RMSEA < .06, and CFI > .95, although for our complex model, these are somewhat rigid standards (Hu & Bentler, 1999). The fit for each survey version is good (Table 1).

Table 1: *CFA Goodness-of-Fit Indices*

S-STEM Survey	χ^2	*df*	χ^2 *p*-value	CFI	RMSEA	SRMR
Middle/High	9,842.668	568	<.0001	.945	.045	.048
Upper Elementary	3,417.252	568	<.0001	.933	.039	.044

Notes: CFI = comparative fit index; RMSEA = root-mean-square error of approximation; SRMR = standardized root-mean-spare residual.

We used Cronbach's alpha to asses internal consistency for each survey version using both years of data. The values were very good for each attitude construct (Table 2).

Table 2: *Cronbach's Alpha for S-STEM Constructs*

S-STEM Survey	Mathematics	Science	Engineering/ Technology	21st Century Skills
Middle/High	.90	.89	.90	.92
Upper Elementary	.85	.83	.84	.87

Measurement invariance was assessed for various demographic groups to determine if these groups exhibit similar measurement properties for each survey version. We examined configural, metric, and scalar invariance and assessed results through alternative fit indices such as CFI, TLI, and RMSEA. Primarily, we used change in CFI as the primary test, with a change between the levels of testing of less than .01 indicating invariance (Cheung and Rensvold, 2002). We compared three types of groups: differing age-ranges (4th versus 5th grade, 6-8th vs 9-12th grade); genders; and races/ethnicities (White/Caucasian, Black/African-American, and Hispanic/Latino). For both survey versions we found measurement invariance held for all three levels of testing, other than for the gender comparison on the Upper Elementary S-STEM Survey. This test found a change in CFI of .011 when testing scalar invariance, potentially indicating a problem, although minor.

In general, our findings for both versions of the S-STEM Survey indicate the instruments are valid, reliable, and fair.

T-STEM Survey

<u>*Survey Content*</u>

The T-STEM Survey gathers information from teachers on various aspects of their teaching related to STEM. Five versions have been developed, one for each STEM content area (science, technology, engineering, and mathematics), and one for elementary teachers. Each survey contains seven constructs, other than the elementary teacher survey which contains nine. The seven basic constructs are given in Table 3.

Table 3: *T-STEM Survey Summary*

Construct	Versions	Measurement Application
Personal Teaching Efficacy and Beliefs (PTEBS)	Science, Technology, Engineering, Mathematics	self-efficacy and confidence related to teaching the specific STEM subject
Teaching Outcome Expectancy Beliefs (TOES)	Science, Technology, Engineering, Mathematics	degree to which the respondent believes, in general, student-learning in the specific STEM subject can be impacted by actions of teachers
Student Technology Use	Science, Technology, Engineering, Mathematics, Elementary	how often students use technology in the respondent's classes
STEM Instruction	Science, Technology, Engineering, Mathematics, Elementary	how often the respondent uses certain STEM instructional practices
21st Century Skills Attitudes	One Version	attitudes toward student learning opportunities for 21st century skills
Teacher Leadership Attitudes	One Version	attitudes toward teacher leadership activities
STEM Career Awareness	One Version	awareness of STEM careers and where to find resources for further information

The first two constructs, PTEBS and TOES, were adapted from the Science Teaching Efficacy Beliefs Instrument (STEBI; Riggs & Enochs, 1990). Some aspects of the STEBI were dated, so we revised the constructs to be more appropriate for modern teachers. We also edited the items to use student growth language instead of student achievement language, and we removed confusing and negative wording. Further, several items form the original survey were removed. The items were created to be parallel in the different versions of the survey, and only subject-specific identifiers, like references to "science" or "mathematics," were changed. The Elementary T-STEM Survey includes these constructs for both mathematics and science fields since most elementary teachers teach both, hence the two extra constructs found in this survey version.

Two other constructs are similarly identical across the survey versions except for the subject identifiers. Of these, the Student Technology Use construct was developed from the Student Technology Needs Assessment (STNA; SERVE Center, 2005), and the STEM Instruction construct was based on items used in a statewide assessment of North Carolina's Race to the Top grant (Corn et al., 2013). These two constructs ask teachers to assess how often students perform certain tasks within their particular STEM field and begin with the question stem, "During [science/technology/engineering/mathematics] instructional meetings…" In the Elementary T-STEM Survey the question stem reads, "During elementary STEM instructional meetings…"

The remaining three constructs are identical across the five survey versions. The 21st Century Skills Attitudes construct parallels the similarly-titled construct from the S-STEM Survey, but asks teachers if they think it is important for students to have learning opportunities in these areas (Friday Institute, 2010). Items from the Teacher Leadership Attitudes construct directly relate to the North Carolina Department of Public Instruction's professional standards for educators (2012). Finally, the STEM Career Awareness construct was newly developed for the T-STEM survey and asks teachers to rate their awareness of STEM careers and STEM career resources.

Five constructs (PTEBS, STOES, 21st Century Skills Attitudes, Teacher Leadership Attitudes, and STEM Career Awareness) use a five-point Likert scale (*Strongly Disagree* to *Strongly Agree*). Student Technology Use and STEM Instruction assess how often students engage in particular activities, and therefore use a five-point scale from *Never* to *Every Time*.

Psychometric Properties

The various versions of the T-STEM Survey were evaluated using exploratory factor analysis with principal axis factoring and promax rotation. Loadings above .3 were classified as significant. However, we were not able to collect enough data to fully analyze each survey. Data is still being collected on the T-STEM Survey instruments, so soon we hope to be able to have full results.

In the meantime, we have used as much data as possible to analyze the survey structure. For example, the three constructs that are identical across survey versions used data from all five versions to run factor analysis. The mathematics PTEBS and TOES constructs were identical on the Mathematics and Elementary T-STEM Surveys, so data from both surveys were used to assess those constructs. Full sample sizes can be seen in Table 4, along with reliability levels. As you can see, due to small sample sizes, were we not able to calculate reliability levels or factor analysis for each construct and survey version. As more data is gathered, factor analysis will be rerun in a more robust manner for each survey version.

Table 4: *Cronbach's Alpha for T-STEM Constructs*

Construct	Number of Items	Construct Version	Sample Size for analysis	Cronbach's Alpha
Personal Teaching Efficacy and Beliefs	11	Science	338	0.92
		Technology	58	-
		Engineering	9	-
		Mathematics	253	0.94
Teaching Outcome Expectancy Beliefs	9	Science	338	0.84
		Technology	58	-
		Engineering	9	-
		Mathematics	253	0.87
Student Technology Use	8	Elementary	192	0.94
		Science	139	0.90
		Technology	58	-
		Engineering	9	-
		Mathematics	88	-
STEM Instruction	14	Elementary	192	0.95
		Science	139	0.93
		Technology	58	-
		Engineering	9	-
		Mathematics	88	-
21st Century Learning Attitudes	11	All	488	0.95
Teacher Leadership Attitudes	6	All	488	0.87
STEM Career Awareness	4	All	488	0.95

*Levels calculated for n over 100

Based on the limited sample sizes, though, results were excellent, with all items loading on their expected construct with no cross-loading. We are still collecting data until our sample sizes are large enough to perform CFA.

P-STEM Survey

Survey Content

The P-STEM Survey measures principal leadership for STEM education in their school. The survey is still in development and final factors have not been determined. Generally, the 37 items in the most current version of the survey ask principals to self-assess their leadership for STEM along the following, broad dimensions: instructional technology; teaching and learning about STEM careers; STEM instructional practices, such as project-based learning and performance assessments; STEM education culture, such as focus on innovation and collaboration and authentic learning; and best practices for educational leadership, like distributed leadership practices.

The original Pilot P-STEM Survey was based on a similar survey developed by The Friday Institute to measure principal leadership for one-to-one laptop initiatives (Friday Institute for Educational Innovation, 2010b). The pilot was designed to measure principal leadership for STEM education along six dimensions: vision, infrastructure, professional development, shared decision-making, advocacy, and evaluation. Initial exploratory factor analysis results from 115 principals, though, found that the items did not fall into the six expected factors. Therefore, after the pilot survey analysis, the survey items were almost entirely reworked, including removal of items and inclusion of new ones. During this process an additional literature review was conducted and key elements of STEM programs as identified by the North Carolina STEM Program Implementation Rubric were reviewed. After this analysis 20 new items were added. Fifteen subject-matter experts, including several principals of STEM schools in North Carolina and national-level researchers, rated the items in the revised version of the P-STEM Survey as "Essential," "Useful but not Essential," or "Not Necessary." Lawshe's content validity ratio was then calculated, problematic items were removed, and new items were added to fill in remaining gaps identified by the subject-matter experts. At this point, the revised P-STEM Survey contained a total of 42 items.

These second pilot P-STEM Survey items begin with the stem, "Regarding the STEM program, I…" and use a five-point Likert scale (*Strongly Disagree* to *Strongly Agree*). Through exploratory factor analysis (see below), the survey was found to have two, clear factors. Additional investigation to confirm meaning and external validity of the constructs is planned subsequent to the writing of this paper. However, preliminary review suggests that the first construct of 18 items measures traditional aspects of principal leadership for general education, and the second construct of 19 items measures contemporary aspects of principal leadership for STEM education. The first factor, which we are terming "General Leadership for STEM," includes more general items such as, "Support teachers to have students work in teams," and "Enable collaboration of teachers across content areas." The second factor, "Specific Leadership for STEM," contains items that address aspects of more contemporary STEM education movements, such as, "Feel knowledgeable about the characteristics of STEM teaching," and, "Support the formal, in-school provision of authentic learning experiences connected to current STEM industries for students."

Psychometric Properties

The P-STEM Survey is still in development, because we have not yet had a large enough sample to run confirmatory factor analysis or measurement invariance testing. However, EFA results on the revised P-STEM Survey exhibit a strong two-factor structure that we believe will hold when a CFA is run in the future.

After the pilot P-STEM Survey was tested and edited, the revised P-STEM Survey was analyzed using data collected from 113 principals. Loadings above .3 were classified as significant. Principal axis factoring with promax rotation was used on the 42 items. Parallel analysis indicated that a two-factor solution was best. Five items were found to cross-load (loadings of .3 on more than one factor) and were removed, leaving 37 items. These items comprise the constructs described in the previous section. Cronbach's Alpha for the first construct, General Leadership for STEM, was .95, and for Specific Leadership for STEM was also .95.

The findings and robust development procedure thus far suggest that the P-STEM Survey will exhibit strong factors in the CFA, once sample sizes permit analysis.

Examples of How Surveys Have Been Used

The research team has used the S-STEM, T-STEM, and P-STEM Surveys in multiple research and evaluation projects.

The MISO Project

The MISO Project, funded by the National Science Foundation (DRL 1038154), seeks to determine the collective impact of STEM outreach programs at North Carolina State University. The MISO Project staff has been using the S-STEM and T-STEM Surveys to collect information about the impact of 28 pre-college and extension programs on approximately 500 students and 300 teachers in North Carolina, annually. Outreach programs specifically directed at students include week-long camps and programs that serve students across multiple school years. Outreach programs that aim to support teachers use a variety of models, from those that provide direct online and face-to-face professional development for STEM educators to those that connect teacher-leaders with STEM businesses and industries. Survey administrations are conducted at the beginning and end of each of the programs that are at least one week long. Unique identifiers for each student and teacher are tracked so that the pre- and post-results may be compared at the individual participant level. Additionally, the MISO Project staff collects student achievement data from the state administrative records and college-going data from the National Student Clearinghouse, as well as teacher self-reported data on licensure and educational attainment. To date 4,444 S-STEM Surveys and 750 T-STEM Surveys have been administered in the MISO Project (miso.ncsu.edu).

Wake County Public School System STEM Network Schools

Located in central North Carolina, the Wake County Public School System is a large, primarily urban school district with 171 schools, including 26 "STEM Network" elementary, middle, and high schools (https://www.wcpss.net/what-we-teach/programs/stem.html). These STEM Network schools focus on implementing teaching and learning strategies built around the engineering design process and project-based learning, and the schools also make special efforts to leverage business and community partnerships. In 2013 the district formed a partnership with the MISO Project research team, administering the S-STEM Survey to all 5th, 8th, and 11th grade students in all STEM Network schools. The district wanted to begin collecting longitudinal information about the impact of their efforts on student attitudes toward STEM subjects and careers, and the research team was able to use the data to compare against other data collected from a rural initiative (see below).

Table 5: *S-STEM Surveys Administered to STEM Network Schools in the Wake County Public School System*

S-STEM Survey	2013	2014
Upper Elementary	1,187	960
Middle/High	2,252	1,646

The Golden LEAF Foundation STEM Initiative

In 2010 the Golden LEAF Foundation (Golden LEAF), based in Rocky Mount, North Carolina, launched a public school "STEM Initiative." It focused on preparing 4th through 9th grade students in North Carolina's rural, economically distressed, and/or tobacco-dependent counties for careers requiring science, technology, engineering, and mathematics (STEM) skills. In the spring of 2011 fourteen grants were funded for a three-year period. The smallest grant was $100,000 to support a single-school and the largest was $600,000 to aid a regional collaboration. Every grant program provided students with opportunities for hands-on, inquiry-based STEM learning and professional development opportunities for teachers. These grants' work affected 43 school districts and thousands of students over the life of the initiative, from spring 2011 through spring 2014. Golden LEAF contracted with members of our research team to conduct a cluster, outcome evaluation at the initiative-level; individual grants were not evaluated. The evaluation applied a mixed-methods approach to explore the ways in which the initiative was effective in changing teacher instructional practices in STEM, student attitudes toward STEM, and student learning in STEM. The S-STEM, T-STEM, and P-STEM Surveys were each administered annually (the P-STEM was not administered in the first year), and individual identifiers were not collected. Annual cohort data was compared, along with results from interviews, focus groups, classroom observations, implementation rubrics, and collections of school-level administrative data on student achievement.

Table 6: *S-STEM, T-STEM, and P-STEM Surveys Administered in the Golden LEAF STEM Initiative Evaluation*

Survey	2011-12	2012-13	2013-14
S-STEM			
Upper Elementary	785	3,433	2,375
Middle/High	8,360	8,404	9,040
T-STEM			
Science	222	149	98
Technology	54	42	54
Engineering	13	9	15
Mathematics	118	98	25
Elementary	236	246	92
P-STEM			
	-	107	113

Evaluation Capacity-Building

Our research team has also completed evaluation capacity-building work, supporting the MISO Project partners, Wake County Public School System staff, and the grantees in the Golden LEAF STEM Initiative to use the S-STEM and T-STEM Surveys. Evaluation capacity-building activities consisted of: the provision of one-page guides for analyzing, interpreting, and reporting survey results; webinars and face-to-face workshops addressing topics such as creating logic models, asking good evaluation questions, collecting data, analyzing S-STEM and T-STEM Survey data with Excel, and interpreting survey data; one-on-one assistance in creating tables of survey results; and one-on-one assistance on reporting results to stakeholders.

Researcher Requests to Use S-STEM and T-STEM Surveys

Since January 2012 outside researchers have been able to request to use the S-STEM and the T-STEM Surveys through the MISO Project website. To date, 267 requests have been made for the S-STEM Survey and 210 for the T-STEM. These myriad researchers have cited the following intentions for their use of the surveys (in order from most to least frequent):

1) Grant proposals;
2) Dissertation research; and
3) School, district, or program evaluation.

Lessons Learned regarding Survey Results, Evaluation Design, and Evaluation Capacity-Building

Results

Our most robust analyses thus far have been conducted on the S-STEM Survey data. When examining sub-group comparisons by age, gender, and race/ethnicity of student attitudes toward STEM subjects, we find that the largest differences are between male and female attitudes toward engineering and technology. Male and female students tend to have similar attitudes toward science and mathematics, but females have largely lower interest in engineering and technology compared to males (Unfried, Faber, & Wiebe, 2014a). Also, we find that student attitudes toward all subject areas decline as the school-level of students increases from upper elementary, to middle, and to high school. When studying student interest in STEM careers, results suggest that student interest again tends to decline as student school-level increases from upper elementary, to middle, to high school (Unfried, Faber, & Wiebe, 2014b). Findings also indicate that males have largely higher interest in engineering careers and this interest is more stable across school-levels than for females. This is the largest, most consistent gap in career interest-levels between all of the sub-group comparisons. Males also have higher interest in core STEM career pathways – consisting of physics, mathematics, computer science, energy, and engineering, and occasionally chemistry and earth science – than females, who instead are mostly ambivalent. At the same time females seem to have higher interest in biological and medical science careers than males, who are mostly ambivalent in this case.

Results from the T-STEM Survey administration in the Golden LEAF STEM Initiative Evaluation suggest that over the three-year initiative: teachers' knowledge of careers in STEM fields increased; teachers felt confident in their teaching abilities, and science and mathematics teachers grew slightly more confident; teachers' attitudes toward 21st century skills remained positive every year; and teachers remained divided on whether classroom efforts of teachers, in general, impact student learning.

Only the pilot version of the P-STEM Survey has been administered, therefore results from this survey are not yet available.

Evaluation Design

Our research team's experiences administering the S-STEM and T-STEM Surveys (the P-STEM Survey is too recently developed) suggest that a pre-post survey design works best for measuring changes in student and teacher attitudes and beliefs toward STEM subjects. Formal tests have not been conducted, but anecdotal evidence suggests that the surveys detect changes in student attitudes and teacher self-efficacy and beliefs after an intervention has been in place for at least two years. Both surveys have been through extensive psychometric testing and provide the strongest results when analyzed at the construct-level. Furthermore, to get a more comprehensive understanding of the impact of STEM program, the surveys work well when combined with results from other data sources like focus groups and interviews and student achievement records. Ideally, individual identifiers can be tracked for each respondent of the survey; results are more precise when compared at the individual-level than at the cohort-level.

Evaluation Capacity-Building

The research team's experience working with school district administrators across North Carolina suggest that while evaluation capacity needs vary by users, some common needs did exist. These needs included the need to acquire knowledge and skills related to: creating program logic models; asking good evaluation questions; understanding and using construct scores from survey data; making sub-group comparisons; calculating basic, descriptive results from survey data; building tables for reporting; and understanding limitations of survey data. The research team has received significant amounts of positive feedback regarding the evaluation capacity-building work, and plan to continue building these activities into evaluations using the S-STEM, T-STEM, and P-STEM Surveys in the future.

For access to the full surveys, please visit our website at http://miso.ncsu.edu/articles/s-stem-survey or http://miso.ncsu.edu/articles/t-stem-survey and fill out the Instrument Request Form.

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