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Development of Instruments to Assess Students' Spatial Learning Attitudes (SLA) and Interest in Science, Technology and Geospatial Technology (STEM-GEO)

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Abstract: Two new instruments were created to assess secondary students' (ages 14-18) spatial learning attitudes and their interest in science and technology, related careers ideas and perceptions about geospatial technologies. These instruments were designed to evaluate the outcomes of a geospatial learning curriculum project. During a two-year period, we explored the use of these instruments during the prototype testing and pilot testing of a series of socio-environmental science investigations. The instruments were implemented with 664 ninth grade urban students from a population traditionally underrepresented in STEM-related fields. Both classical and Rasch analyses were conducted each year to optimize the instruments. The resulting 24-item Student Interest in Science, Technology and Geospatial Technology (STEM-GEO) measure and 9-item Spatial Learning Attitudes (SLA) measure had high internal consistency reliabilities (Cronbach's Alpha) as well as acceptable Rasch reliabilities. Content validity and construct validity evidence were also summarized and discussed.

Keywords: *Survey development, STEM careers, spatial attitudes, geospatial technologies, Rasch rating scale modeling.*

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Introduction

The U.S. Department of Labor has identified geospatial technology as a sector "projected to add substantial numbers of new jobs to the economy or affect the growth of other industries or are being transformed by technology and innovation requiring new sets of skills for workers" (National Geospatial Advisory Committee, 2012, p. 4). Despite accelerating industry growth and congruence across science, technology, engineering, and math, disciplines collectively known as STEM, few school-based programs integrate geospatial technology within their curricula. Geospatial thinking and reasoning skills are essential for occupations in which geospatial analysis skills for solving problems is either critical to the job or enhances occupational competence where there is a heavy reliance on cognitive thinking skills that include knowledge about geospatial relations and geospatial reasoning skills (Goodchild & Janelle, 2010; NRC, 2006). These skills involve important scientific practices highlighted in the Next Generation Science Standards [NGSS] (NGSS Lead States, 2013), and include data manipulation, analysis, data mining, and modeling that provoke and *require* critical thinking and problem solving that are connected to data referenced to Earth's surface or to the Earth's representation through map and globe visualizations (Huynh & Sharpe, 2013). GIS is now the standard for spatially referenced data management, but STEM curricula often include learning experiences that do not match the analytic practices that are critical for success in STEM-based occupations (Aikenhead, 2005; Chin, Munby, Hutchinson, Taylor, & Clark, 2004). Science curricula that engage students to collect and analyze data, consider multiple hypotheses, and solve problems allow students to rehearse important skills that help prepare them for career opportunities and lifelong learning (National Research Council, 2011; National Science Board, 2015).

Previous studies have confirmed that spatial ability is a significant factor in science subject achievement (Lubinski, 2010; Wai, Lubinsky, & Benbow, 2009). For many concerned with broadening access to and involvement in the sciences, these findings are significant, especially since studies have confirmed that gender plays a role in some spatial abilities inherent in STEM disciplines (Voyer, Voyer, & Bryden, 1995). This research has led to calls for improving spatial thinking skills in girls, including recognition that spatial skills can be developed (National Research Council, 2006); encouraging educational activities that use spatial thinking skills (Hill, Corbett, & St. Rose, 2010); and using geospatial tools to promote critical thinking, analysis, and reasoning in problem solving (U.S. Department of Labor,

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2010). A meta-analysis conducted by Uttal et al. (2013) concluded that a spatially embedded curriculum can succeed in developing STEM performance and participation. Globally, curriculum that integrates geospatial technologies are viewed as an important mechanism for promoting spatial thinking skills development, spatial knowledge, and classroom engagement (Milson, Demirci, & Kerski, 2012; Battista & Manaugh, 2017; Rickles, 2017; Wise, 2018; Zwartjes, 2018; Liu, et al., 2019).

To address these needs and build upon earlier findings, we developed a curriculum project aimed at secondary students who are typically underrepresented in STEM-related fields to provide them with technology-rich geospatial learning experiences to develop their content knowledge about important environmental issues and promote thinking and reasoning skills that are needed for entering the STEM workforce. In the United States, those who are traditionally underrepresented in STEM-related fields include people from non-dominant racial, ethnic, and economic cultural backgrounds such as low-income, Black, Latino, and English-learning populations (Burke, 2007; Tate, 2001). In upper secondary U.S. schools, many students from these populations are unengaged learners who are not concerned with achievement in school, avoid challenging work, and often do not complete learning tasks (Sanacore, 2008). The project was funded by the National Science Foundation's Innovative Technology Experiences for Students and Teachers (ITEST) program. The goals of this program are to increase student awareness of STEM and information and communications (also commonly referred to as ICT) careers, motivate students to pursue the education necessary to participate in STEM and ICT careers through technology-rich experiences, and provide students with technology-rich experiences that develop their knowledge of STEM-related content and skills needed for entering the STEM and ICT workforce sectors (National Science Foundation, 2019).

An important aim of the ITEST program is to advance understanding of how to foster student interest and capacities to participate in the STEM and ICT workforce of the future. Student attitudes and interests towards STEM can be influenced by their learning experiences (Weinberg, Basile, & Albright, 2011; Brown et al., 2016). Strategies to promote interest in STEM careers include participation in authentic projects that are personally relevant and meaningful to students (Christensen & Knezek, 2015). Further, the incorporation of locally relevant data collection and analysis using ICT can increase student engagement and promote scientific skill development (Reid-Griffin & Carter, 2008).

To assess the effectiveness of such curriculum projects, researchers have either developed or adapted related measures that focus on STEM career attitudes and interests. For example, the Educational and Career Interest Scale was developed to measure high school students' educational and career interests related to science, technology, and math (Oh, Jia, Lorentson, & LaBanca, 2013). The STEM Career Interest Survey measured self-efficacy, outcome expectations, personal inputs, and contextual supports and barriers as predictors of STEM career interest among middle school students (Kier, Blanchard, Osborne, & Albert 2014). The Student Interest in Technology and Science (SITS) survey assessed secondary learners' interest in learning science, using technology to learn science, science careers, technology careers, and attitudes toward biotechnology that played a biotechnology learning game (Romine, Sadler, Presley, & Klosterman, 2014). Tyler-Wood, Knezek, and Christensen (2010) developed a STEM Career Interest Questionnaire for their energy home monitoring and analysis project with middle level learners.

A limitation of using existing instruments is that they are not designed for specific secondary student populations, especially those who may be English learners or those unengaged to complete lengthy survey instruments. In a review of available instruments to measure student attitudes towards interest in STEM, Romine et al. (2014) identify nine instruments, ranging in length from 40 to 245 items. These measures had not been used with populations of economically disadvantaged students and such lengthy instruments may not be appropriate to use with unengaged secondary students who are not concerned with achievement in school (Sanacore, 2008).

Over a two-year period in our project, we developed, prototype-tested, and then pilot-tested a series of geospatial socio-environmental science investigations (SESI) and projects. One of the challenges to assess the effectiveness of our project was to develop psychometrically rigorous measures to ascertain student *interest* in science and technology careers and student *attitudes* towards geospatial technologies. Our literature review revealed no existing measures that specifically aligned to our project needs—measuring secondary students' STEM-related *learning interest*, *interest in using technology* to learn science, STEM-related *career interests*, *attitudes* about *geospatial technology*, and *spatial learning attitudes* that have been used with a population of urban secondary students, all being economically disadvantaged with a high percentage identified as unengaged learners. Thus, we identified existing related measures that focused on STEM career attitudes and interests as a starting point to create a measure of Student Interest in Science, Technology and Geospatial Technology (STEM-GEO) and a Spatial Learning Attitudes (SLA) measure for our project.

Research Focus

The primary aim of this research was to develop and validate two new instruments, the *Student Interest in Science, Technology and Geospatial Technology (STEM-GEO)* and *Spatial Learning Attitudes (SLA) measures*, that could be used to measure students' interest in science and technology, related careers interests, perceptions about geospatial technologies, and attitudes towards using maps and technologies such as mobile devices and computers that use map-

based imagery for learning. Since learning with geospatial technologies was a primary focus of our ITEST socio-environmental curriculum project, these instruments included items designed to understand students' ideas with regards to how geospatial technology can help learners understand their local community and address problems in our society.

A secondary focus of this work was to explore the efficacy of our pilot-tested SESI investigations with regards to students' interest or perceptions mentioned above. The research questions explored were:

1. After pilot-testing the SESI investigations, was there any change in students' expressed interest in learning science, interest in STEM-related careers, or their perceptions of using map-based technologies for learning?
2. How did the students who pilot-tested the SESI investigations change in their responses regarding interest in learning science, interest in STEM-related careers, or their perceptions of using map-based technologies for learning, as compared to a control group who did not use the SESI investigations?

The SESI Investigations

SESI are inquiry-based investigations designed to take advantage of recent developments in powerful, mobile geospatial technologies to promote STEM-related workforce skills. The content of SESI focuses on social issues related to environmental science. The pedagogy is inquiry-driven, with students engaged in map-based mobile data collection followed by analysis with Web-based dynamic mapping software to answer open-ended questions. The investigations are multi-disciplinary, involving decision-making based on the analysis of geospatial data in both social studies and environmental science contexts.

SESI activities are based on the pedagogical frameworks of place-based education and socio-scientific issues-based instruction. Place-based education focuses on local or regional investigations, is designed around engaging students in examining local problems (Sobel, 2004), and utilizes fieldwork to gather evidence in that local setting (Semken, 2005). Socio-scientific issues are socially relevant, real-world problems that are informed by science (Sadler, Barab, & Scott, 2007). Addressing them requires the use of evidence-based reasoning, and provides a context for understanding scientific information through an active approach to learning, while placing science content within a social context. This combination of content and context supplies both motivation to and the ownership of learning by the student (Sadler, Barab, & Scott, 2006; Zeidler & Nichols, 2009). The SESI investigations therefore address authentic issues and incorporate data collection and GIS analysis to investigate students' local contexts, thus enabling learners to understand how their local issues fit into larger regional and global issues (e.g., Atzmanstorfer, Resl, Eitzinger, & Izurieta, 2014).

The SESI investigations focus on students' immediate urban environment and connect the Next Generation Science Standards (NGSS) crosscutting concepts and scientific practices to disciplinary core ideas in Human Sustainability (NGSS Lead States, 2013). The investigations are designed for students to gather georeferenced data with GPS-enabled iPads that are essential to each investigation, and place emphasis on socioscientific issues that are real-world problems related to environmental science. The investigations require students to gather information relevant to their own communities. Students are then asked to take on the role of a decision-maker, and inform their thinking and reasoning about decisions based on their analysis of the data they gather, its connection to relevant social and environmental science content, and consideration of the implications for social equity and environmental sustainability.

Each SESI investigation focuses on a driving investigative question and specific content for implementation in a science classroom (ecosystem services, urban heat island), a social studies classroom (urban zoning, land use change over time), or both (healthy natural and built environment). Concurrently with this content learning, each investigation is designed to develop students' geospatial process skills. These skills include accessing different geospatial applications (Collector app on iPad and Web GIS maps on laptop computers), utilizing data collection procedures, displaying and navigating maps, annotating maps, analyzing data using different tools for pattern recognition and examining outliers, and constructing new data displays and visualizations.

Urban Heat Islands (UHI) is an example of a SESI investigation. In this investigation, students learn about heat absorption and re-radiation from different parts of the natural and built environment. The investigation culminates in a proposed change to local neighborhoods to reduce the heat island effect. The first step in the investigation is a presentation from the teacher about the scientific concepts involved urban heat island effects. Next, students download a map of a sampling area to the ArcGIS Collector app on their GPS-enabled iPad. Next, they go outside with their iPads and infrared surface temperature thermometers. Working in pairs or trios, students go to an assigned zone on the school property to obtain temperature readings from various surfaces found within their zone, including asphalt, concrete, grass, bare soil, and other surfaces that the students observe.

Once back in the classroom, the data from the iPads are synced into a class-wide dataset. Next, the students examine the collected data using ArcGIS.com and observe the patterns in temperatures recorded on different surfaces (e.g., dark asphalt vs. light asphalt, or concrete vs. grass) and under different conditions (shaded vs. unshaded, or morning vs. afternoon). Figure 1 shows the contrasts that students could observe between shaded areas, such as the tree-lined area

on the western edge of the data collection area (yellow and light orange colors), versus the hotter temperatures recorded in the middle of the parking lot (red and dark orange colors).

Figure 1. Data collected during the UHI investigation. Colored data points display surface temperature.

In the next step of the investigation, students analyze a GIS map of the land cover in their city. This map displays both built environment features (structures, roads, impervious surfaces such as parking lots) and natural features that help reduce the urban heat island effect (vegetation and tree canopy, including trees that shade structures and roads). Students then examine an assigned neighborhood in their city (see Figure 2) to analyze the land cover and discuss how it contributes to the urban heat island effect.

Figure 2. Land cover map allowing students to study urban heat island effects across the entire city. The blue polygons are assigned neighborhoods for student groups to examine a suburban neighborhood (west side of map), a commercial district (center), and a dense residential district (east).

After discussing the existing land cover and possible mitigation strategies, students propose several changes for their assigned neighborhood. For example, students suggested converting dark rooftops to light-colored rooftops, creating shade by adding rows of trees within parking lots, modifying large commercial structures to incorporate green roofs, and other recommendations that increase reflection and decrease solar energy absorption by a surface. Students then use the suite of draw tools to make these changes on their ArcGIS.com map and submit their recommendation to their teacher (see example in Figure 3).

Figure 3. Sample student product from the Urban Heat Island investigation. To reduce the UHI effect in the assigned zone, this student has added a green roof with a garden (purple), white roof instead of a black roof (pink), and changed street to light asphalt (yellow).

Initial Survey Development

We conducted a comprehensive literature review to identify existing valid and reliable instruments that were designed to measure secondary students' interest in learning science and science-related careers, interest in using technology to learn science, interest in careers in technology, attitudes towards geospatial technology, and spatial thinking attitudes. We started with a review of existing measures that have measured STEM career attitudes and interests (e.g., Kier et al., 2014; Oh et al., 2013; Romine et al., 2014; Tyler-Wood et. al, 2010) and spatial learning attitudes (Kim & Bednarz, 2013; Shin, Milson, & Smith, 2016).

We adopted the format of the Student Interest in Technology and Science (SITS) survey (Romine et al., 2014) for our STEM-GEO measure. The SITS instrument included three sections that included ideas about learning (10 items), ideas about careers (10 items), and ideas about biotechnology (5 items). Items from the SITS survey that were deemed relevant to our context were modified to reflect the nature of socio-environmental investigations. For instance, the

term "science" was modified to "science-related". As an example, an item in the SITS instrument, "I enjoy using technology to solve science problems" was modified to "I enjoy using technology to investigate science-related problems." In addition, selected items that used the term "computers" in the SITS instrument was changed to "technology", to encompass the multiple technologies used in the SESI investigations. In U.S. STEM education, technology is often used as a tool in science, engineering or mathematics activities. The second section of the SITS instrument primarily focused on biotechnology careers. Given that the SESI investigations were designed to promote geospatial careers, we revised the wording of eight items in this section to focus on technology-related fields, science-related fields, and field settings to better reflect the career field of the geospatial technology sector. The third section of the SITS instrument focused on ideas about technology. Four of the five items were significantly modified to encompass ideas about geospatial technology. In addition, two items were added to reflect how geospatial technology can be used to understand and explore one's local environment, which included: (1) Using geospatial technology improves our ability to understand our community and (2) Using geospatial technology with gaming (such as Pokemon Go!) is useful for exploring my environment.

Our initial STEM-GEO survey consisted of 26 Likert items, each with a response scale from 1 to 5 (with 5 being *most agreeable*). The survey was divided into three sections: ideas about learning (10 items), ideas about careers (10 items), and ideas about geospatial technology (6 items).

Our Spatial Learning Attitudes (SLA) survey was designed for students to share their ideas about spatial learning that involves using maps and technologies (e.g., mobile devices and computers that use map-based imagery) for learning. Five items originated from the Attitude toward Spatial Thinking Inventory (Shin, Milson, & Smith, 2016) and were modified to simplify the language for our study. These items were also modified to include digital map-based imagery. The initial measure consisted of 12 Likert items, each with a response scale from 1 to 5 (with 5 being *most agreeable*).

To further establish content validity, six experts from the STEM and geospatial education fields reviewed all items in both instruments and provided feedback that were incorporated in the measure revision. In addition, an expert in the field of English language learners reviewed the language of all items to ensure acceptable readability for our target population that included 20% language learners.

Methodology

Setting, Participants, and Context

Year 1: Prototype Testing

The sample in Year 1 consisted of 93 students in the 9th grade (ages 14-18) in an urban public high school in the northeast United States. The students attending this school were all economically disadvantaged—all students received free breakfast and lunch. The sample included 39 males, 53 females, and 1 student that did not identify with a specific gender. The race/ethnicity of the students included 65 (69.9%) Hispanic, 16 (17.2%) Black, 9 (9.7%) White, and 3 (3.2%) who did not respond. Fourteen (15.1%) were identified as English learners and 12 students (12.9%) had Individualized Education Programs (IEPs). These students represent populations that are traditionally underrepresented in STEM-related fields (Connors-Kellgren, Parker, Blustein, & Barnett, 2016).

Year 2: Pilot Testing

The sample in year 2 consisted of 571 students in the same school district as Year 1 and comprised of two groups of students: (1) a group of 149 ninth grade students (ages 14-18) from one school that pilot tested seven SESI investigations and three related geospatial projects (i.e., SESI group); and (2) another group of 422 ninth grade students (ages 14-18) from two other schools with the same student population demographics who did not use the SESI investigations (i.e., non- SESI group). The SESI group included 77 males, 67 females, and 5 students that did not identify themselves with a specific gender. The race/ethnicity of the SESI group students included 90 (60.40%) Hispanic, 33 (22.15%) Multi-racial, 13 (8.72%) Black, 10 (6.71%) White, and 3 (2.01%) Others. Eleven (7.40 %) were classified as English learners and 23 students (15.40%) had IEPs. The non-SESI group included 188 males, 224 females, and 9 students that did not identify themselves with a specific gender. The race/ethnicity of the other group of students included 244 (57.96%) Hispanic, 115 (27.32%) Multi-racial, 27 (6.41%) Black, 19 (4.51%) White, and 15 (3.56%) Others.

In the SESI group, the SLA and STEM-GEO pretest measures were completed by 149 students and the posttests were completed by 114 students. In the non-SESI group, the pretest survey measures were completed by 407 to 419 students and the posttest survey measures were completed by 124 students. While the reduced number of students completing the posttest measure in the SESI group was consistent with the school district's student attrition rate, there were survey distribution issues in the non-SESI schools that resulted in a lower post - survey completion.

Data Analyses for Both Year 1 and Year 2

Descriptive statistics were checked for all items, and then for the entire and subscale summation measures of the initial SLA (12 items in Year 1, reduced to 9 items in Year 2) and STEM-GEO (26 items in Year 1, reduced to 24 items in Year 2) surveys. Exploratory Factor Analysis (EFA) was conducted in SPSS, first for Year 1 pretest data of each survey, and then verified with Year 1 posttest and Year 2 data. Principal Axis Factoring (PAF) was employed with Promax for rotation for EFA. Internal reliability using Cronbach's alpha was checked for each entire survey, and then for each factor (subscale) within each survey.

As part of the construct validity evidence, in addition to the classical EFA and reliability analyses, a series of Rasch analyses using the rating scale model (see below) were run for data in both years. Rasch analyses were run first for each entire survey—SLA and STEM-GEO, and then were repeated for each subscale of STEM-GEO, since the data were multidimensional as identified by EFA and by the overall Rasch analysis. Each analysis reported below met the Rasch unidimensional assumption (measuring a single or dominant construct), with ordered category and threshold measures (Linacre, 2002). We also examined Rasch item fit statistics, person and item reliabilities, and person-item (Wright) maps (see below). If any misfitting items emerged, we reran the Rasch analyses by removing the misfitting items iteratively.

Rasch Rating Scale Model

The Rasch model (Rasch, 1960) predicts the probability of a student to answer a test item correctly as a joint function of the student's *ability* (generic wording for the underlying construct) and the item *difficulty* (how hard it is to get the item correct). The Rasch Rating Scale Model (Andrich, 1978) is an extension from the binary Rasch model for polytomous (multi-categorical) survey data and thus, is the specific model underlying all the Rasch analyses in this study. Compared with classical test theory, the Rasch measurement approach has been popular for providing item-level information and promising group- and test-independence; namely, respondents' ability and item parameter estimation may remain invariant, regardless of the survey items and respondents, if the data-model fit is present.

Our Rasch analyses were conducted using the Winsteps computer program (Linacre, 2019). Item fit statistics in the form of mean squares (chi-square statistic divided by its degrees of freedom) were used for this study. The expected *mean*-square value being 1.0, the range 0.5 to 1.5 was deemed to support productive measurement. Rasch person and item reliability indices informed us how well the items and persons separate along the continuum of construct, thus providing more detailed information between the properties of an item on an instrument and individuals responding to those items. Variable maps available from Winsteps output provides an overall picture of the person-ability distribution and the item-difficulty distribution along the same measurement scale. Thus, the maps may visually clarify the need for iterative survey refinement based on our theoretical definition of the measured construct.

Results for Year 1 (Prototype Testing)

Students completed the STEM-GEO and SLA pretest measures in September. Three SESI investigations were prototype-tested with the students during 13 March – 2 May of the school year. Students completed the STEM-GEO and SLA posttest measures in May after the completing the prototype SESI investigation.

Table 1 displays the resulting reliability summaries from the entire SLA and STEM-GEO Version One pretest and posttest. The initial 12-item SLA pretest data yielded three factors in EFA, but included one factor with two items only, loading less than .90. The cumulative percentage of variance accounted for reached 73% for SLA pretest data. We reran EFA for the pretest data, forcing 2 factors for the survey. We then removed three items due to their cross loading, item content redundancy, and an item that had language issues for the student population. EFA was rerun and yielded one factor for remaining nine SLA items. The reliability summaries for the SLA pretest and posttests with the removal of the three items are presented in Table 2. The Cronbach's Alpha indicated high internal consistency reliabilities for the pretest and posttest. This provides evidence that the SLA survey is measuring what we want it to measure. The resulting 9-item SLA survey items are in Appendix A.

Both the initial 26-item STEM-GEO Year 1 pretest and posttest data yielded 4-factor structures, which were quite similar to each other and also consistent with the factor structure from the literature. The cumulative percentage of variance accounted for reached 73% for STEM-GEO pretest data and 69% for STEM-GEO posttest data. We went through all the EFA results, and decided on the final factor structure that should be most meaningful and/or consistent with the relevant theory and our expectation as content experts. Meanwhile, we decided to drop two items for cross loading. The remaining 24 items still pointed to a 4-factor structure in EFA. The reliability summaries for the STEM-GEO pretest and posttest entire measure and the resulting four subscales are presented in Table 2. The Cronbach's Alphas indicated high internal consistency reliabilities for the entire STEM-GEO measure and each subscale.

Table 1. Reliability Summaries for Instruments Version One (n=93)

	Cronbach's α	
Instrument	**Pretest**	**Posttest**
Spatial Learning Attitudes (12 items)	.792	.797
STEM-GEO (26 items)	.960	.957

Table 2. Reliability Summaries after Question Removal (n=93)

	Cronbach's α	
Instrument and Subscale	**Pretest**	**Posttest**
Spatial Learning Attitudes (9 items)	.923	.855
STEM-GEO entire measure (24 items)	.958	.955
STEM-GEO Subscale 1 (8 items)	.918	.927
STEM-GEO Subscale 2 (5 items)	.888	.901
STEM-GEO Subscale 3 (5 items)	.919	.934
STEM-GEO Subscale 4 (6 items)	.919	.894

Note. SLA with 3 items removed; STEM-GEO with 2 items removed

Rasch analyses were run (and rerun when misfitting items emerged) for both the entire pretest and then the entire posttest survey after we removed three SLA items, and two STEM-GEO items. The analyses were repeated for each subscale (factor) as suggested by the EFA in SPSS. Rasch person reliability (.88) and item reliability (.90) was high for the SLA pretest. Two misfitting items on the pretest were kept because each item (1) had a low percentage of unexpected responses (around 5%) and (2) was no longer misfitting in Rasch analyses of the posttest data. For the SLA posttest, Rasch person reliability (.83) and item reliability (.90) were high. No misfitting item came up in Rasch analyses on the posttest data.

Rasch person reliability (.88) and item reliability (.93) was high for the STEM-GEO entire pretest and for each of the four subscales. Rasch person reliability (.88) and item reliability (.93) was high for the STEM-GEO entire posttest. Rasch person reliability was high for each of the STEM-GEO posttest subscales, but mostly had low item reliabilities (e.g., below .80), possibly due to homogeneous STEM-GEO item responses and the limited sample size. Three of the subscales had low item reliability which was deemed acceptable since the survey was not designed to discriminate among the participants.

The resulting STEM-GEO survey items are in Appendix B. Table 3 displays the four resulting subscales and corresponding item numbers.

Table 3. STEM-GEO Subscales and Corresponding Item Numbers

Subscale	**Item #s**
1. Interest in learning science and science-related careers	1, 3, 5, 11, 13, 14, 17, 18
2. Interest in using technology to learn science	2, 4, 6, 7, 8
3. Interest in careers in technology	9, 10, 12, 15, 16
4. Attitudes toward geospatial technology	19, 20, 21, 22, 23, 24

Results for Year 2 (Pilot Testing)

Students completed the STEM-GEO and SLA pretest measures in September and the posttest measures in May. Seven SESI investigations and three related projects were pilot-tested with the SESI group students during the school year. Table 4 displays the resulting reliability summaries from the SLA and STEM-GEO pretest and posttest for all students. The Cronbach's Alphas indicated high internal consistency reliabilities for the both the SLA and STEM-GEO measures and each STEM-GEO subscale. For the SLA measure, Rasch person reliability (.81 for pretest and .84 for posttest assessments) and item reliability (.99 for pre- and .98 for posttest assessments) were both high, meeting the unidimensional assumption for each separate analysis (pretest and posttest), with ordered category and threshold measures. When the year 2 STEM-GEO pretest items were run together, the overall Rasch analysis output pointed to multi-dimensionality with four distinct subscales. Across all four subscales for the pretest survey, Rasch person reliabilities and item reliabilities were both high (above .80). For the posttest survey, Rasch person reliabilities and item reliabilities were both high for all subscale, except for the Rasch item reliability for subscale 4, which was possibly due to the smaller N and homogeneous responses. The Wright map for each Rasch analysis was checked and did not contradict our expectation.

Table 4. Pre-post Cronbach's alpha for SLA and STEM-GEO (Entire and Subscales)

	(Sub-)Scale	Pretest (*N* = 571)	Posttest (*N* = 238)
SLA	Unidimensional (9 Items)	α = .791	α = .851
STEM-GEO	Entire Scale (24 items)	α = .924	α = .943
	Interest in learning science and science-related careers (8 items)	α = .893	α = .911
	Interest in using technology to learn science (5 items)	α = .807	α = .879
	Interest in careers in technology (5 items)	α = .872	α = .915
	Attitudes toward geospatial technology (6 items)	α = .817	α = .886

Table 5. Rasch Person and Item Reliabilities for STEM-GEO Subscales

Subscale	Rasch Person Reliability		Rasch Item Reliability	
	Pretest	Posttest	Pretest	Posttest
Subscale 1	0.88	0.89	0.98	0.95
Subscale 2	0.84	0.86	0.81	0.84
Subscale 3	0.88	0.88	0.96	0.92
Subscale 4	0.81	0.84	0.82	0.67

Note. Pretest *N* = 571; Posttest *N* = 238.

Exploration of SESI Investigation Research Question

After the pilot-testing the SESI investigations, was there any change in students' expressed interest in learning science, interest in STEM-related careers, or their perceptions of using map-based technologies such as mobile devices and computers for learning? Among the 149 students in the SESI group who completed the pretest measures at the beginning of the school year in September 2017, 114 students completed the posttest measures in May 2018. Attrition was 35 students (23.5%). Table 6 shows the descriptive statistics (means and SDs) and paired-sample *t* tests for the means of the pretest-posttest SLA and STEM-GEO survey measures and subscales. No significant differences between pretest and posttest were found for each of the three measures, $p > .05$. That is, the pilot-testing of the SESI investigations did not result in any changes in students' interest in learning science and science-related careers, interest in using technology to learn science, interest in careers in technology, attitudes toward geospatial technology, and their perceptions of using map-based technologies such as mobile devices and computers for learning.

Table 6. Summation Measure Descriptive Statistics and Paired-Sample t-Tests for the SESI group only

	Pre		Post		Paired *t*-test (2-tailed)		
Scale	Mean	SD	Mean	SD	*t*	df	*p* value
SLA Entire Scale	29.11	5.97	28.86	6.28	0.40	113	.693
STEM_GEO Entire Scale	78.51	14.98	76.82	17.03	0.93	113	.357
STEM-GEO Subscale 1	24.21	6.48	23.75	6.78	0.64	113	.520
STEM-GEO Subscale 2	17.53	4.03	17.00	4.34	1.02	113	.309
STEM-GEO Subscale 3	17.41	4.32	17.19	4.58	0.42	112	.673
STEM-GEO Subscale 4	19.54	3.72	19.04	4.88	0.96	112	.338

Note. After listwise deletion of missing data, *N* = 114 for each of the first four tests and 113 for each of the last two tests, which is also reflected by the degree of freedom (*df*).

How did the students who pilot-tested the SESI investigations' change in their responses regarding interest in learning science, interest in STEM-related careers, or their perceptions of using map-based technologies such as mobile devices and computers for learning compare to a control group who did not use the SESI investigations? The results based on a series of mixed ANOVA with repeated measures (pre-post) between the two groups (SESI vs. non-SESI) for the SLA and STEM-GEO entire and subscales are displayed in Table 7. No significant differences were found from pre- to posttest, between the two groups, and/or for their interaction, for either the SLA, or any of the STEM-GEO entire measure and its subscales. That is, there was no difference between the two groups with regards to students' interest in learning science and science-related careers, interest in using technology to learn science, interest in careers in technology, attitudes toward geospatial technology, and their perceptions of using map-based technologies such as mobile devices and computers for learning.

Table 7. ANOVA for Pre-Post and Group Mean Comparisons, Using Summation Measures for Year 2 SLA and STEM-GEO Entire and Subscales

Scale	Group	Pre		Post		*N*	Sig. tests *p* values		
		Mean	SD	Mean	SD		Time (Pre vs. Post)	Group	Time x Group
SLA Entire Scale	SESI	29.11	5.97	28.86	6.28	114	.418	.812	.828
	non-SESI	29.36	5.89	28.93	6.65	122			
STEM_GEO Entire Scale	SESI	78.51	14.98	76.82	17.03	114	.364	.065	.592
	non-SESI	74.09	18.79	73.65	20.69	121			
STEM-GEO Subscale 1	SESI	24.21	6.48	23.75	6.78	114	.828	.115	.212
	non-SESI	22.31	7.86	22.98	7.94	121			
STEM-GEO Subscale 2	SESI	17.53	4.03	17.00	4.34	114	.119	.296	.978
	non-SESI	17.00	4.73	16.49	4.99	120			
STEM-GEO Subscale 3	SESI	17.41	4.32	17.19	4.58	113	.617	.178	.840
	non-SESI	16.64	4.71	16.55	4.79	117			
STEM-GEO Subscale 4	SESI	19.54	3.72	19.04	4.88	113	.290	.117	.678
	non-SESI	18.64	4.41	18.42	4.89	118			

Discussion

A main goal of this work was to develop reliable measures to ascertain student interest in science-related and technology careers, and attitudes towards geospatial technologies with a secondary student population of urban learners that were predominantly economically disadvantaged and included a substantial number of students that are unengaged learners, do not complete learning tasks, avoided challenging work, and do not seem concerned with achieving in school (Sanacore, 2008). Given the geospatial context of our work, we were especially interested in secondary students' STEM-related learning interest, interest in using technology to learn science, STEM-related career interests, attitudes about geospatial technology, and spatial learning attitudes. A review of the literature drew attention to the need for the development of a new measure that could be used for geospatial learning projects that focus on developing important STEM-related skills and spatial learning dispositions for particular student populations that have been traditionally underrepresented in STEM-related fields due to non-dominant racial, ethnic, and economic cultural backgrounds such as low-income, Black, Latino, and English-learning populations (Burke, 2007; Tate, 2001).

In this study, we underwent a two-year process to design, validate, prototype test, and pilot test new survey measures to address this need in the education field. The resulting STEM-GEO and SLA surveys measure secondary students' STEM-related learning interest, interest in using technology to learn science, STEM-related career interests, attitudes about geospatial technology, and spatial learning attitudes. The instruments underwent a validation process with experts in the STEM education and the geospatial technology teaching and learning field. Further, to ensure that the items were comprehensible for English language learners, the items were reviewed by an educator with expertise with teaching English learners. During the two-year study, the survey measures were optimized using both classical analyses and item response theory through iterative prototype testing and pilot testing with secondary students from a population that have been historically marginalized with access to STEM-related career fields. During the two-year prototype- and pilot-testing of the SESI curriculum materials, 31.2% of the ninth grade students in the SESI group were identified by both the researchers and the classroom teachers as unengaged learners. That is, they did not complete learning tasks, avoided challenging work, and did not seem concerned with achieving in school (Sanacore, 2008). The majority of the SESI group students were able to complete the STEM-GEO and SLA measures within ten minutes. Thus, the design of the surveys for this intended student population was deemed effective.

Curriculum projects that use geospatial technologies that include GIS or other dynamic mapping applications are rapidly emerging school settings as a way to promote STEM-related skills and access to important STEM-related career pathways (see Milson et al., 2012). GIS is now the standard technology for spatially-referenced data management and new STEM curricula such as the SESI investigations or citizen science projects (see Wallace and Bodzin, 2017). These projects include learning experiences that match the analytic practices that are critical for success in many STEM-related occupations (National Geospatial Advisory Committee, 2012). GIS is extensively used in civil and environmental engineering, the geosciences, urban and regional planning, environmental resource management, surveying and cartography, agriculture, conservation, national resource management, public health, transportation, wildlife ecology, landscape architecture, and among others. School-based curriculum has a unique role in developing important STEM-

related skills, promoting positive dispositions toward learning science, and creating learning environments that encourage students onto pathways toward STEM careers (Connors-Kellgran, Parker, Bluestein, & Barnett, 2016). Students' attitudes toward STEM are an important factor influencing their motivation to learn STEM subjects and to pursue a STEM career (Maltese & Tai, 2011). Therefore, measures such as the STEM-GEO and SLA surveys provide an important attitudinal tool for geospatial curriculum projects.

The primary aim of this study was to develop valid and reliable measures to ascertain student interest in science-related and technology careers, and attitudes towards geospatial technologies that could be used with a secondary students population that may likely to be unengaged to complete a lengthy survey instruments. A secondary goal of this study was to report on the use of the STEM-GEO and SLA surveys with a secondary student population that is traditionally underrepresented in STEM-related fields. We were interested if learning with a series of SESI investigations throughout the school year would have a positive impact on students' STEM-related learning interest, interest in using technology to learn science, STEM-related career interests, attitudes about geospatial technology, and spatial learning attitudes. The pretest and posttest analyses resulted in no significant changes across these constructs. In addition, there were no significant differences found between students who used the geospatial investigations and a comparison group of students who did not use the SESI investigations.

During the year two pilot testing, the SESI group students completed seven SESI investigations and three comprehensive geospatial projects that involved proposal writing and developing a presentation. The results for the STEM-GEO and SLA measures might be due to the fact that two projects were implemented sequentially during the last six weeks of the school year. As noted above, the majority of students were reluctant to engage in detailed proposal writing tasks. Due to the development schedule, these projects were the last curriculum learning materials to be created. There was a reluctance of many students to complete the multi-part learning tasks and comprehensive writing tasks of the last two projects. Only 79 of the 113 students (70%) completed the last geospatial project. A different instructional sequence that would intersperse the projects throughout the academic school year may have provided different results.

Conclusion

This study presents a new valid and reliable instrument for measuring secondary students' STEM-related learning interest, interest in using technology to learn science, STEM-related career interests, attitudes about geospatial technology, and spatial learning attitudes that can be used with secondary students who are typically underrepresented in STEM-related fields that include learners who are unengaged in school learning and do not seem concerned with school achievement. Educators have recognized that school curriculum that use geospatial technologies have the capacity to promote spatial thinking by enabling powerful visualization, analysis, and synthesis of georeferenced data to expand student understandings of science (NRC, 2006). As more curriculum-based geospatial technology projects are emerging to provide students with technology-rich experiences that develop their knowledge of STEM-related content and skills needed for entering the STEM and ICT workforce sectors, there is a need for measures such as the STEM-GEO and SLA surveys to assess the effectiveness of such projects.

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Appendix A. Spatial Learning Attitudes Survey Items

1. I find it easy to see patterns and relationships among things.
2. Maps help me learn.
3. I am good at reading and interpreting phone app maps.
4. I am good at reading and interpreting paper maps.
5. I like reading and interpreting paper maps.
6. When I am thinking about a complex idea, maps, diagrams and pictures help me understand.
7. I like to use maps on a smartphone to explore my environment.
8. I like to use maps on a computer to explore information in maps.
9. I am good at using computer technology to learn from maps.

Appendix B. Student Interest in Science, Technology and Geospatial Technology (STEM-GEO) Items

1. I enjoy learning science.
2. I enjoy using technology to investigate science-related problems.
3. I plan to take more science-related classes in high school.
4. Technology helps me learn science.
5. More time in the school day should be devoted to science-related learning.
6. Technology makes learning science more interesting.
7. I enjoy using technology to learn science.
8. More time in science classes should involve the use of technology.
9. I would be more likely to take a job if I knew it involved working with technology.
10. Having a job in a technology-related field would be interesting.
11. I would like to work in a science-related area.
12. I would like to get a job in a technology-related field.
13. I would like to work in a science-related field that uses technology.
14. I would like to work with people who solve science-related problems with technology.
15. I would enjoy a job that uses technology.
16. I will probably choose a job that involves using technology.
17. I would enjoy working in a science-related related field.
18. I would like to work in a science laboratory or field setting.
19. Using geospatial technology (such as GIS) helps find solutions to problems in our world.
20. Geospatial technology is important for our society's development.
21. Using geospatial technology improves our ability to understand our community.
22. Geospatial technology is important for modern life.
23. Geospatial technology is useful for the problems of everyday life.
24. Using geospatial technology with gaming (such as Pokemon Go!) is useful for exploring my environment.