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Development and Psychometric Assessment of Measures for a Novel STEM Pathway Program that Represents a Partnership between an Academic Health Professions University and High Schools in Underserved Oregon Communities

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Abstract

Purpose: To understand the impact STEM programs have on Black, Native American, and Latinx communities, validated measures are needed. After conducting a literature review on relevant STEM constructs, we developed a survey-based instrument tailored to our STEM program and administered it to 217 high school students in 2019. We conducted an exploratory factor analysis to identify relevant domains and psychometric properties. **Main Results:** Two components loaded, the first we labeled Sense of Self as a Science Learner, defined as a personal view of one's uniqueness as a health and science learner. Seven items loaded with an Eigenvalue of 6.11 and total explained variance of 43.6% with a Cronbach's Alpha Coefficient of 0.88. We labeled the second component Self-efficacy in Pursuit of a Science Career, defined as a belief in one's own abilities to successfully achieve career goals. Six items loaded with an Eigenvalue of 1.78 and total explained variance of 12.8% with a Cronbach's Alpha Coefficient of 0.78. **Contribution:** We successfully developed and rigorously tested an instrument tailored to our STEM program that accurately measures Sense of Self as a science learner and Self-efficacy in pursuit of a science career among Oregon urban and rural high school students of color.

Keywords: STEM Program Evaluation; Psychometric Analyses; Students of Color; Self-efficacy; Sense of Self; Science identity; High School

Introduction

In 2001, the National Science Foundation introduced the term STEM in reference to the disciplines of Science, Technology, Engineering and Mathematics [1]. Shortly thereafter, several key reports highlighted the links between prosperity and knowledge-intensive jobs that were dependent on science and technology careers [2,3]. These reports also indicated that the United States was lagging behind other countries in the proportion of college students receiving degrees in science or engineering. These data resulted in the development of studies on educational practices that would lead high school graduates toward attaining essential STEM knowledge and competencies needed for success in post-secondary education.

While many studies focused on increasing the quality of the K-12 STEM teaching force and identifying best practices in STEM education toward scaling them broadly [4,5] several barriers to implementing evidence-based instructional practices have been identified. These barriers include lack of training, time, and incentives, as well as using personal experiences rather than evidence-based instruction [6-8]. Further, many studies address a wide age range from K-12 to undergraduate and graduate education [9-11], and significant variability exists within and across STEM programs [10,12-14].

STEM programs often focus on increasing students' interests in health and science careers, and when implemented for underrepresented minority students (URM), they can also increase racial diversity in health sciences education, creating a healthcare workforce that more closely matches the demographics of the U.S. population [15]. This is important because the lack of racial diversity in health professions has been identified as a major contributor to health disparities in the U.S. [16]. Typically, students self-select into STEM programs, but URM students often lack access to STEM programs [17]. Research by Danner et al. [12] shows that exposure to medical careers and increased interactions with medical staff and college advising positively influences health career choices among URM students. Of note is that these studies use the term URM to describe their populations.

We acknowledge the need to change this nomenclature, given that Whites will be in the minority in the U.S by 2045 [18]. Thus, we use the term students of color rather than URM. Though measures exist to assess science interest, identity and growth mindset [19-21], these measures are not typically tailored to specific components of a given STEM program, and information on their reliability and validity among students of color is lacking.

In 2013, we developed a novel STEM education program called On Track OHSU! (On Track), which represents a unique partnership between Oregon Health & Science University (OHSU), school districts, and tribal communities that work with students of color, including Black, Native American and Latinx students. Though income level is not an inclusion-criteria for On Track, the majority of On Track students included in this study were eligible for Free and Reduced Lunch, a federal guideline that is a common marker of income level in the United States (U.S.). In 2018/19, when this study was conducted, the income guideline for Free and Reduced lunch inclusion was an annual pre-tax income for a family of four of $46,435 or 185% of the U.S. poverty level [22]. OHSU, an academic health professions university with schools of dentistry, medicine, nursing, pharmacy and public health is the sponsoring institution for On Track, which works closely with community and school partners to learn about the community's goals and to tailor the program to meet community specific needs.

On Track was designed to develop interest, science identity, growth mindset and educational value among student participants through exposure to health and science careers, role modeling, college advising and relational support throughout their middle school, high school and post high school years. While these are key features of many STEM programs [23-25], we have been challenged by the lack of existing measures that are both sensitive enough to evaluate the specific experiences On Track offers and that have also been validated with students of color. In previous years, we used the PEAR Institute's STEM Common Instrument [21], but data derived using these instruments were difficult to interpret because the instruments did not align with our specific educational activities, and the full age range of high school students we study were not consistently included in their measures. A search of the literature indicated that exposure to growth mindset programming can lead to improved grades in STEM [11,26], but most measures were designed for older students [19], or focused on measuring motivation and engagement [9] or adoption of teaching strategies [20].

Due to the lack of measures on identity, interest, growth mindset and educational value in high school settings for students of color, we developed our own survey-based instrument that aligns specifically with On Track program objectives and visit specific outcomes. We administered it to 217 On Track high school students during the 2018/2019 academic year and conducted an exploratory factor analysis to identify the relevant domains our measures were assessing and their psychometric properties. Here we report on measurement development and psychometric testing from our work with two of the school districts with whom we partnered.

Methods

On Track Program Development

Though the focus of this paper is on high school students, a brief description of On Track, which also served middle school students, is relevant. On Track was developed in 2012 to increase the participation of Black, Native American and Latinx students in OHSU's schools and programs. Working closely with our community educator partners, we started with students in the 6th grade and continued to work with the same students through their middle and high school years and beyond. Engaging students early is important because studies have shown that early exposure to informal STEM experience has a significant effect on STEM identity formation and the pursuit of STEM degrees [27]. Because, as mentioned, we use a community-generated approach with solutions that are specific to each of our partner communities, some program components vary. On Track currently collaborates with eight middle and five high schools in four Oregon communities, one of which is rural and majority Latinx, two that are rural and predominately Native American and one that is urban with a racially diverse population where one third of students are Black.

On Track High School Program

The high school program is designed to increase students' interest in, awareness of, and preparation for health and science secondary education and careers. All activities have engaging hands-on components that occur both at the high school and at OHSU. In-school visits involve small group learning opportunities with OHSU undergraduate and graduate students, as well as those from other local universities, who share their own unique pathways into their fields of study. OHSU based visits are designed to introduce high school students to a variety of health science students and faculty in fields that range from certificate programs (e.g., Emergency Medical Technician Certificate) to physicians (MD), dentists (DMD), nurses (e.g., BSN, MS, PhD) or basic scientists or clinical researchers (MS, MPH, PhD).

On Track high school students have additional optional opportunities to further develop their identity as science learners that include volunteering to work with middle school students in the On Track program, participating in week-long clinical shadowing, and participating in research events during spring and summer breaks. These more in-depth experiences are stepping stones for On Track students toward full summer research internships and/or clinical volunteer programs. On Track high school students also receive assistance in academic planning and advising, financial guidance, and assistance with scholarships applications. After each high school visit and at the end of the year, students complete surveys about their experiences and are invited to participate in focus groups. All On Track program and evaluation components have been reviewed and approved by both OHSU's Institutional Review

Board (IRB #9904) and the Northwest Portland Area Indian Health Board's IRB. In addition, each school district reviewed and approved program and evaluation activities and provided specific requirements for students' participation.

Measurement development

Members of the On Track author group, including KB, KL, and SS, conducted a literature review on concepts relevant to STEM. Key words included science identity, growth-mindset, and perseverance in STEM careers. Particular emphasis was placed on instruments to measure students' interest in STEM activities with students or color and or Native American/Alaskan in programs that occurred outside regular classroom activities. The inclusive dates of review included 1/01/13 to 5/20/19, and included MEDLINE, PubMed, etc., databases. While the search did reveal survey instruments that included our population, they did not capture the goals of the programs. We then held a brain-storming session (which also included authors PAC and AM) to develop a question set for high school students that would help us assess the development of identity, interest, growth mindset and educational value that would be sensitive enough to measure On Track-specific high school program components. This evidence-guided brainstorming session produced 13 questions according to the initial domain codes we chose, which are shown in Table 1.

Survey Question number	Survey Item	Domain Area
1	Participating in *On Track* has made me more interested in a health or science field.	Development of Health/Science Interest
2	Because of *On Track*, I am interested in exploring more health and science careers.	
10	*On Track* has made me want to learn more about different pathways into health and science fields).	
3	I am open to learning new strategies that can help me understand something that is challenging.	Development of Growth Mindset
5	When I come across something difficult, I give myself time and space to find a solution instead of giving up.	
8	If I am struggling to learn something new, I feel comfortable finding someone to help me work through it.	
4	Because of *On Track,* I know it is important to take challenging math and science classes in high school.	Sense of Educational Value
6	Being part of *On Track* helps me and my classmates think about our futures.	
12	I look forward to *On Track* activities.	
7	Participating in *On Track* makes me believe I can pursue my goals after graduating from high school.	Development of Health/Science Identity
9	Through *On Track*, I've met somebody at OHSU who has a job I could do one day	
11	Because of *On Track,* I can see myself being happy in a health or science field one day.	
13	I would like to volunteer with *On Track* (or a similar program) after I graduate high school.	

Table 1: Initially developed survey items, according to proposed domain area.

Three questions were initially developed to assess the Development of Health/Science Interest, three were designed to assess Development of Growth Mindset, four were developed to assess the Development of Health/Science Identity, and three were designed to assess Sense of Educational Value. The response scale had four points (1=Definitely No, 2= No, 3= Yes; and 4=Definitely Yes). Importantly, 10 of 13 (76.9%) variables specifically mention the impact On Track had on these learners, providing the context we found lacking in prior surveys used. The surveys additionally collected students' gender and grade level.

Though we designed our survey questions with face validity in mind, they required formal psychometric testing to determine factor loadings (actual measurement domains) and validity properties of the measure. To achieve this, we administered the surveys to 217 students from two Oregon high schools that partner with On Track, one in an urban setting, and one in a rural setting. Survey administration occurred at the end of the 2018-19 program year, after all On Track activities had been completed.

Data analysis

All study data were checked for completeness and inconsistencies and errors were corrected prior to analyses. All data were de-identified for analyses. Frequencies and representative percent were used to characterize students' gender and grade level. We used a conservative 15 respondents per variable tested [28], which indicated we needed 195 respondents for a minimum sample size and were able to attain 217 respondents. The extraction method for this exploratory factor analysis was principal component analysis with a Varimax rotation method using Kaiser Normalization. The rotation converged in three iterations. After reviewing the variables that loaded, the On Track team labelled and defined the components that loaded. Here we report the rotated component matrix, the variable names and definitions, the Eigenvalues, percent of explained variance, number of items, mean scores and Cronbach's Alpha Coefficients. SPSS version 25 was used to conduct analyses.

Results

The characteristics of students in terms of gender and grade are outlined in Table 2. Female high school students predominated with 69.1% compared to 30.9% of males. The largest group of participants were 10th graders (31.3%), and the smallest were 9th graders (17.1%).

Two components loaded in this exploratory factor analysis (Table 3), the first of which we labelled Sense of Self as a Science Learner. We defined this component as a personal view of one's uniqueness as a health and science learner. Seven items loaded to this component with a range in rotated components in the matrix of 0.576 to 0.855, an Eigenvalue of 6.11, percent of total variance explained was 43.6%, the mean score was 3.2, and the Cronbach's Alpha Coefficient was 0.88. Rotated components in the matrix that did not load ranged from 0.021 to 0.411. We labelled the second component that loaded as Self-efficacy in Pursuit of a Science Career, which we defined as a belief in one's own abilities to successfully achieve career goals. Six items loaded to this component and its range in rotated components in the matrix was 0.596 to 0.717, an Eigenvalue of 1.78, percent of total variance explained of 12.8%, a mean score of 3.3, and the Cronbach's Alpha Coefficient was 0.78. Rotated components in the matrix that did not load ranged from 0.092 to 0.301.

Grade	Males n (Row %)	Females n (Row %)	Total n (Column %)
9th Grade	7 (18.9%)	30 (81.1%)	37 (17.1%)
10th Grade	23 (33.8)	45 (66.2%)	68 (31.3%)
11th Grade	19 (35.2%)	35 (64.8%)	54 (24.9%)
12th Grade	18 (31.0%)	40 (69.1%)	58 (26.7%)
Total	67 (30.9%)	150 (69.1%)	217 (100%)

Table 2: Characteristics of students included in the factor analysis.

Initial Domain Code	Question Number	Survey Item	Component #1: Sense of Self as a Science Learner n=217	Component #2: Self-Efficacy in Pursuit of a Science Career n=217
Interest	3	Participating in *On Track* has made me more interested in a health or science field.	0.855	0.092
	4	Because of *On Track*, I am interested in exploring more health and science careers.	0.851	0.135
	10	*On Track* has made me want to learn more about different pathways into health and science fields.	0.725	0.236
Identity	9	Through *On Track*, I've met somebody at OHSU who has a job I could do one day.	0.645	0.152
	11	Because of *On Track*, I can see myself being happy in a health or science field one day.	0.856	0.167
	13	I would like to volunteer with *On Track* (or a similar program) after I graduate high school.	0.679	0.257
Educational Value	12	I look forward to *On Track* activities.	0.576	0.301
Growth Mindset	3	I am open to learning new strategies that can help me understand something that is challenging.	0.151	0.717
	5	When I come across something difficult, I give myself time and space to find a solution instead of giving up.	0.021	0.744
	8	If I am struggling to learn something new, I feel comfortable finding someone to help me work through it.	0.274	0.596
Educational Value	4	Because of *On Track*, I know it is important to take challenging math and science classes in high school.	0.071	0.680
	6	Being part of *On Track* helps me and my classmates think about our futures.	0.388	0.603
Identity	7	Participating in *On Track* makes me believe I can pursue my goals after graduating from high school.	0.411	0.610
		Component Values		
		Eigenvalues	6.11	1.78
		% of Total Variance	43.6	12.8
		Number of Items	7	6
		Mean Scores (SD-Standard Deviations)	3.2 (0.53)	3.3 (0.4)
		Cronbach's Alpha Coefficients	0.88	0.78

*Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 3 iterations.

Table 3: Rotated Component Matrix*

Discussion

This study contributes to the literature in several important ways. First, it represents a rigorous psychometric assessment of an instrument designed to both align with program elements and measure important components related to helping high school students from racially diverse backgrounds, the majority of whom fell into a lower income U.S. federal guideline, to consider careers in health and science. This study is also novel in that it was based on specific activities undertaken in partnership between an academic health professions university located in the Pacific Northwest and high schools in urban and rural settings with students that are racially underrepresented in health and science professions. We learned that all 13 questions we initially developed loaded to one of two domains identified in this exploratory factor analysis and that the internal consistency is stable to high, as reflected in the Cronbach alpha coefficients. This indicates that the question set captured measurable components related to the educational activities that On Track has developed and implemented for high school students.

We expected that the four domain areas we initially constructed (development of health/science interest, growth mindset, health/science identity, and sense of educational value), would each be differentiated in the factor analyses. However, only two components actually loaded, which we labelled: Sense of Self as a Science Learner and Self-efficacy in Pursuit of a Science Career. Upon reflection, these findings make sense. We defined Sense of Self component as reflecting learners' personal views of their identity traits and their uniqueness, all of which are consistent with a level of maturity we would expect to find among high school students. These are the variables that loaded to this component. Further, Vincent-Ruz and Schunn [29] have suggested interest and identity are tied together, given that one is more likely to be interested in science activities if they have a science identity. We also know that other factors have been tied to science identity, including authentic science experiences and intrinsic and extrinsic factors [29], which are components of the On Track high school program, so this is consistent with our findings. Conversely, the concepts of interest, growth mindset, science identity and educational value are typically first introduced in STEM programs during middle school [30,31] where level of maturity would be taken into account in program design and assessment activities. These issues would likely be further elucidated when we conduct a factor analysis with data from On Track middle school students, where we might find the domains we initially identified would be more likely to load as important factors.

The second component that loaded was Self-efficacy which we defined as a belief in one's own abilities and self-direction that helps learners successfully achieve goals in life. Self-efficacy is consistent with On Track's goal to increase students' growth mindset, where students have an underlying belief that learning and intelligence can grow with time and experience. The variables that tended to load to this domain were growth mindset and educational value, which we considered to be students' experience of the worth or significance of the educational opportunities they were provided with. Development of a growth mindset has been associated with improvements in academic scores [26], though, the picture is complicated. Brougham and Kashubeck-West [32] studied 69 high school students in an underserved high school and found that an intervention designed to develop a growth mindset resulted in higher growth mindset scores; however, this did not lead to improvements in academic performance. Self-efficacy was first identified by Bandura in 1977, which he defined as an individual's belief in their capacity to execute behaviors necessary to produce specific levels of performance [33]. Building on this, Chen and Usher [34] found that self-efficacy can play a primary role in how learners approach goals, tasks, and challenges and may be a better mediating measure of achievement for high school students than growth mindset. Additionally, they found that mastery experiences are a powerful source of self-efficacy and it appears that drawing from multiple mastery sources simultaneously has an additive benefit. These researchers found that students with the most adaptive characteristics had stronger beliefs in the flexibility of their science abilities compared to students with least adaptive characteristics [34]. Our findings suggest that educational value, combined with the growth mindset component, are consistent with the Self-efficacy measure. Certainly, more research is needed to understand the link between measures of self-efficacy, growth mindset, educational value and academic performance.

As mentioned earlier, studies on low income racially diverse students' experiences in STEM are limited. We found one study that focused on urban Black high school students [32], which found that many participants demonstrated levels of aptitude, ambition, and self-initiative; however, these factors were not as salient to the pursuit and persistence in STEM as other factors, such as positive social influences, community building, and sense of belonging. These more salient factors do contribute to the development of self-efficacy and relevant self-identity concepts [32,35]. Further, our review of the literature found that many STEM programs in rural settings are internet-based without any formal evaluation or research design, limiting their utility.

Now that we have validated our instruments, our future plans include assessing trends in the development of Sense of Self and Self-efficacy over time and determining how our programs may be contributing to students' persistence in pursuing their academic goals. We believe such longitudinal results will be consistent with the finding of Oscos-Sanchez et al. [36], who determined that greater participation in medical workshops increased interest in medical careers and persistence in pursuing medical careers. Several studies have found as students age, interest in health and science careers decreases [28,29,31,32,34,36], and we believe we can counter this finding with long-term longitudinal programming that includes strong relationships with students. We hope our planned interventions will support sustained student interest in health and science careers by increasing their Sense of Self as Science Learners and Self-efficacy in Pursuit of Science Careers.

This study could not have been conducted without the high level of commitment for STEM education we have found among the community partner high schools, including students, teachers and school system leaders as well as across

OHSU with its students, faculty and institutional leaders. These relationships helped us overcome barriers that have been reported in other studies [6-8]. Another novel feature of this partnership is access to educational researchers who assisted with item construction, methodological design and psychometric analyses. Such resources are often not available in other STEM settings. Also, critically important from the perspective of supporting participating students and parents, we have engaged On Track Community Liaisons, who are residential members of our partner communities. These liaisons help to establish trusting relationships with students who are often first-generation college applicants and help reduce the barriers for family members who may not have experienced the college application process or financial aid or scholarships application processes.

The strengths of this study include our successful engagement of two of our partner high schools and collection of detailed data from a significant proportion of enrolled Black and Latinx students located in both rural and urban areas. Both the settings and populations included represent populations of interest that are understudied. We also had an abundance of statistical power to conduct the exploratory factor analysis. To understand what measured components emerge for middle school students, a separate factor analysis of data will be conducted after successful completion of data collection.

Weaknesses of this study include that the population was predominantly female, which differs from the representation of all students at the schools with whom we work. This indicates a potential bias associated with students' decisions to participate in On Track. It is difficult to know for sure what impact this gender discrepancy may have on the factor analysis, but we plan to conduct a confirmatory factor analysis next year to assess the stability of the measurement tool.

In conclusion, we successfully developed and rigorously tested an instrument that measures Sense of Self as a Science Learner and Self-efficacy in Pursuit of a Science Career among high school students of color in urban and rural settings who participate in a STEM program that is strongly affiliated with an academic health professions university. Further testing of these measures in other settings in future studies could help other programs similar to On Track understand the impact of the program on Sense of Self as a Science Learner and Self-efficacy in Pursuit of a Science Career.

Declarations

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests: The authors declare that they have no competing interests.

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Authors' Contributions

1. Patricia Carney, PhD, MS: Study concept and design, analysis and interpretation of data, drafting of initial manuscript, and approval of final version.
2. Kathryn Bonuck, MSEd: Study concept and design, data analyses and interpretation, drafting of initial manuscript, and approval of final version.
3. Kathryn Lenahan, BS: Acquisition of funding, acquisition of data and critical revision of manuscript for intellectual content, and approval of final version.
4. Azalea Martinez, BS: Acquisition of data and critical revision of manuscript for intellectual content, and approval of final version.
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