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A Single-Item Measure for Assessing STEM Identity

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Science identity based frameworks have proven fruitful in predicting persistence in careers in Science, Technology, Engineering, and Mathematics (STEM). However, much of the research in this area is qualitative or relies on measures of science identity that have not been validated. Here, we propose and provide initial evidence for the validity and reliability of the single-item *STEM Professional Identity Overlap* measure (STEM-PIO-1) that aims to assess the broader construct of STEM identity via students' perceived overlap between the image they have of themselves and the image they have of STEM professionals. Across three studies, we provide evidence of convergent, discriminant, and criterion validity—the measure displays moderate positive associations with adapted measures of STEM identity, explains unique variance relative to related but distinct measures of STEM identity, and is positively associated with STEM attitudes, STEM self-efficacy, mastery goal orientation, and agentic behavior toward one's graduation goals. The measure differentiates between STEM and non-STEM majors, and is associated with self-reported persistence in one's STEM major. The single-item measure displays moderate test-retest reliability and an expanded four-item version yields good internal consistency. Although continued validation is needed, the simplicity of the STEM-PIO-1 may prove valuable in its ability to promote consistency in measurement of the STEM identity construct across time, age groups, and disciplines.

Keywords: STEM identity, STEM attitudes, STEM self-efficacy, agency, goals

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INTRODUCTION

In recent years, there has been a growing interest in professional identity as a factor that may improve our understanding of the difficulties involved in motivating and retaining students in science, technology, engineering, and mathematics (STEM) fields. Despite widespread knowledge that STEM jobs tend to have higher salaries than other jobs (U.S. Department of Education: Institute of Education Sciences, 2014), and that there is a shortage of qualified individuals to fill STEM positions (Morrison et al., 2011), student interest in pursuing college majors in STEM remains relatively low (Chen and Soldner, 2013). Furthermore, approximately half of the students who initially pursue STEM majors eventually switch to a non-STEM major (Strenta et al., 1994; Seymour and Hewitt, 1997; Daempfle, 2003). The most common explanation for this trend is that students who decide to switch from a STEM major to a non-STEM major do so because they perceive that they lack the requisite competence or skill to be successful. However, even high-ability students fail to persist in STEM (e.g., Webb et al., 2002). This has prompted researchers to examine psychological factors that guide the decisions of students about the costs and benefits of allocating effort toward persistence in their major.

One factor that appears to contribute to persistence in STEM fields is the extent to which the individual possesses a *science identity* (Carlone and Johnson, 2007; Herrera et al., 2012; Hazari et al., 2013; Perez et al., 2014). Science identity can be broadly defined as the aspect of the self that relates to science (Carlone and Johnson, 2007). Overall, science identity among students is quite low, with ∼30% of all students indicating that they view themselves as a "science person," a number that is even lower for women and individuals from groups underrepresented in STEM fields (Hazari et al., 2013). Consequently, interventions that foster STEM identity may be particularly effective in promoting greater persistence in STEM majors. However, before this ideal can be realized, researchers must come to agree on what science identity is, and how it can be measured. The current research seeks to contribute to this conversation by developing and validating a simple and versatile measure of STEM identity.

Research on science identity has predominantly relied on qualitative research, which was necessary to define and provide a rich understanding of the construct (Sfard and Prusak, 2005; Carlone and Johnson, 2007; Herrera et al., 2012). However, qualitative approaches are of limited utility to assess the effectiveness of large-scale interventions aimed at increasing science identity. Efforts to quantify the construct have resulted in a number of author-generated and adapted measures of science identity, most of which have not been validated (e.g., Young et al., 2013; Starr, 2018). As research continues to grow in this area, it is important to develop measures that are validated and which can promote consistency of measurement across research samples. Here, we propose and validate a broad and versatile single-item measure of identification with STEM, the *STEM Professional Identity Overlap* measure (i.e., the STEM-PIO-1). Owing to its simplicity, it is our hope that the measure may provide researchers with an efficient means of assessing STEM identity in large-scale intervention studies, longitudinal work, and with a diverse set of populations that range in age, STEM field, and demographic variables.

What Is Science Identity?

Identity has been defined as a "core sense of self" (Jones and McEwen, 2000). However, this "core" is not unitary, as it is comprised of personal identities as well as many intersecting social identities that serve to foster a sense of belonging to one or more groups (Tajfel and Turner, 1986; Jones and McEwen, 2000). In the development of *Social Identity Theory*, Tajfel (1981) described social identity as "that part of an individual's self-concept which derives from his [or her] knowledge of his [or her] membership in a social group (or groups) together with the value and emotional significance attached to that membership" (p. 255). Developments in self-categorization theory (Turner and Reynolds, 2012) highlighted the important role of context in determining which elements of our identity are activated, such that some contexts elicit more of our personal identity, and others more of our social identity. Moreover, *which* social identity is activated also varies with context, such that a woman in a STEM classroom that is filled with men is likely to have her social identity as a woman activated, whereas when she is with her family, her identity as a daughter or sister may be more likely to be activated. Owing to this, measures of social identity typically reflect specific social identities, rather than a generalized social identity. This specificity has the advantage that context relevant identities (e.g., student, scientist) predict context-specific outcomes (e.g., academic performance and persistence) better than broader social identities (Eccles and Barber, 1999; Bonous-Hammarth, 2000; Osborne and Walker, 2006).

The notion of social identity proposed by Tajfel and Turner (1986) explicitly focuses on the importance and value of social identity to a person's self-concept. This approach to social identity can be broadly construed as identity *centrality* (Leach et al., 2008). However, other research has suggested that social identity is multi-faceted, and includes a facet of *typicality* (referred to as self-stereotyping by Leach et al., 2008; Starr, 2018). This perspective recognizes that two elements are essential for developing a social identity: (1) seeing oneself as a member of the group, and (2) feeling that the members of the group accept you as a member (Kim et al., 2018). Although the first may be captured by the importance of a social group to one's self-concept, the latter may be better captured by the self-perception that you are a prototypical member of the group—that you possess the skills, knowledge, beliefs, practices, and principles of a member of that particular group (Ibarra, 1999; Nadelson et al., 2015).

Measures of science and STEM identity vary in whether they emphasize identity centrality or typicality. For example, Young et al. (2013) developed a multi-item scale assessing the importance of science to one's self-concept, including the item: "Being a STEM student is an important reflection of who I currently am." Other measures have instead emphasized typicality. For example, Hazari et al. (2013) asked participants whether they see themselves as a biology/chemistry/physics person, which appears to reflect typicality more so than importance (i.e., participants must consider whether they match the characteristics of a "biology person"). Nadelson et al. (2015) argued that, for professional identities, it is important to ask students proxy questions for determining the extent to which their attributes, skills, knowledge, etc. match those of a highly identified professional, because otherwise students tend to assume a higher level of identification development than is warranted based on their actual characteristics. Starr (2018) suggested that a focus on typicality may be especially important when people possess stereotypes about a group that do not match their own self-concept – such as an African American female student who possesses the stereotype that scientists are White men.

Consistent with Starr's (2018) rationale for assessing STEM typicality, Carlone and Johnson (2007) made the strong case that students from under-represented groups in science fields may be especially likely to struggle with feeling that they are recognized by others as belonging to a field of science professionals. In their qualitative analysis of science identity, Carlone and Johnson proposed that, in order for individuals to have a strong science identity, they must feel (1) confident that they have (or are capable of acquiring) the knowledge necessary to understand science concepts (i.e., competence), (2) confident in their ability to showcase their science skills in public settings (i.e., performance), and (3) that others—particularly those within the scientific community—recognize their competence and performance (i.e., recognition). Similarly, Herrera et al. (2012) suggested that competence, performance, and recognition interact with an individual's multiple social and cultural identities such that an individual's STEM identity is influenced by the perceived recognition from others, as well as how that individual integrates STEM into his or her sociocultural context.

The process of learning in science is more than just accumulating knowledge because it also involves socializing students into the culture of science. It is, therefore, important to investigate how students come to connect with the culture of science or, alternatively, become alienated from that culture. Carlone and Johnson (2007) argued that, even when students feel competent in their STEM knowledge and possess the requisite STEM skills, they may lack recognition by their peers, family, and—perhaps most importantly—their STEM teachers and professors. Lewis (2003) argued that, "science career attainment is a social process, and the desire of an aspirant is only one factor in this process. An aspiring scientist relies on the judgment and invitation of practicing scientists throughout every phase of the educational and career process" (p. 371). Consequently, those individuals who are perceived as not fitting the traditional "mold" of a STEM professional may highly value science as part of their self-concept, but receive less recognition of their skills and competencies, and ultimately perceive that they do not belong in the field owing to a lack of perceived overlap with the prototypical image of a scientist.

Why Is Science Identity Important?

Individuals who highly identify with science are more likely to make decisions that validate that identity (Eccles, 2009; Herrera et al., 2012; Perez et al., 2014). These students may be better able to maintain their motivation to persist in STEM fields because their efforts are directed toward the pursuit of a science career that aligns closely with their science identity (Oyserman, 2015). Consequently, decisions that divert an individual away from a science career trajectory carry the additional cost of severing part of a highly valued identity. Along these lines, Perez et al. (2014) found that individuals who arrived at the decision to major in a STEM field through a deep exploration of the field, believing that it matched their interests, skills, and prior experiences, were more likely to have positive beliefs about their competence in STEM and the value of a STEM major, than did students who chose their major based on other factors (e.g., parental pressure). Additionally, they perceived the costs associated with a STEM major (e.g., time spent studying) as more worthwhile. Importantly, these variables subsequently predicted students' intention to persist in their STEM major.

Similarly, Kuchynka et al. (2017) found that women's STEM identity provided a buffer against the experience of sexism, such that women with low STEM identity (but not high STEM identity) reported reduced STEM major intentions, STEM self-efficacy, and STEM GPA. Arguing from the perspective of Motivational Intensity Theory (Brehm and Self, 1989; Richter et al., 2016), the authors suggested that STEM identity fosters investment in one's STEM work, which begets motivation to perform well in that domain, and fosters the exertion of effort even when faced with hardship. In contrast, those with lower STEM identity are likely to invest less, be less motivated to perform well, and be more likely to desist in the face of hardship. In other words, STEM identity may play a crucial role in rallying effort during critical moments of hardship when students might otherwise consider changing their major.

Measuring Science Identity

Given the recent interest in promoting the development of science identity, it is important to identify a method for measuring the construct. Most of the research concerning science identity has focused on qualitative measures that allow for a rich characterization of the factors that promote identification with science (e.g., Sfard and Prusak, 2005; Carlone and Johnson, 2007; Herrera et al., 2012). Although extremely informative, qualitative approaches to the measurement of science identity do not provide a way to quantify this identity and are extremely difficult to implement in larger samples. Quantitative approaches to the measurement of science identity have relied on a variety of different assessment strategies. As noted above, Hazari et al. (2013) adapted an item from previous research asking individuals to report the extent to which they see themselves as a science person. In their research, they created separate items for each of three scientific disciplines (i.e., "Do you see yourself as a biology/chemistry/physics person?"). Although face valid, this item may be problematic in that it assumes that one either is, or is not, a science person. That is, it suggests that science identity is an all-or-nothing construct, and that being a scientist is not something that can be learned. This is problematic because identity is dynamic and changes with life experiences (Sfard and Prusak, 2005; Ceglie, 2011).

Measures assessing the importance of science to one's self-concept (e.g., Young et al., 2013) generally focus on the impact that being a science student has on learning material at the present time, not how the student compares himself or herself to other science professionals. This may be an important point given that what limits the development of STEM identity for some students is the perception that their self-concept does not match the attributes of a typical STEM professional. Sfard and Prusak (2005) suggested that identity can be measured as stories about an individual told by an author (the individual or someone else) to a recipient (the individual or someone else). This perspective suggests that identity is shaped by the context, and that it can represent the current state of the individual (the actual identity) or a potential state of the individual (the designated identity). Thus, educational choices can be viewed as a way to close the gap between a student's actual and designated identities; measuring this gap may be useful for predicting persistence, as it connotes the likelihood that effort toward one's goal will be well-spent or wasted. Thus, although existing measures of science and STEM identity have face validity, there is little consistency with regard to how science identity is measured, making it difficult to compare findings across studies.

The STEM Professional Identity Overlap Measure

In creating our measure of STEM identity, we prioritized an emphasis on typicality, that is, an assessment of the extent to which students feel that who they are as a person is compatible with being a STEM professional. This was done with an eye toward future research that will seek to understand why underrepresented groups in STEM do not persist in their majors. The qualitative literature strongly suggests that persistence may be related to recognition from valued mentors, and lack of such recognition may lead to a perceived lack of "fit" with the profession (Carlone and Johnson, 2007). Moreover, a measure that can assess the gap between one's current self and his or her idealized future professional identity was seen as beneficial because gaps that are too large may be highly predictive of the perception of diminishing returns on investments in one's major.

The development of our measure was based on Aron's et al. (1992) measure of interpersonal closeness, in which participants are presented with a set of circles with varying levels of overlap, and are asked to identify one of seven pairs of overlapping circles that best represents the degree to which they feel they have included another person in their own self-concept. This interpersonal measure has been adapted by previous researchers to study other facets of social identity. For example, Tropp and Wright (2001) adapted the measure to assess women's gender identity. Their measure was framed more in terms of identity centrality, asking participants to select the pair of circles "that best represents your own level of identification with your group" (or in other studies, their sense of connection with the group, and their relationship to the group). More recently, Ahlqvist et al. (2013) used Aron et al.'s overlapping circles to measure the stability of female college students' perceived compatibility between their gender and STEM identities.

Our adaptation of this method asks participants to: "*Select the picture that best describes the current overlap of the image you have of yourself and your image of what a STEM professional is*" and uses a similar 7-point pictorial response scale to that of Aron et al. (1992) (see **Figure 1**). This framing permits us to assess perceived overlap with a desired future identity. There is a degree of subjectivity built into the concept of a STEM professional. This is intentional because students' concept of what a STEM professional is may vary considerably based on their experiences. For example, although the stereotype of a scientist may be a White male, some students may have had the opportunity to be mentored by professors or research supervisors who defy that stereotype, thereby changing their image of what a STEM professional is. This shift is important, particularly for students from underrepresented groups (URGs), as it may increase their perceived overlap with STEM professionals, and foster their persistence to achieve that desired end-goal. Moreover, it is likely to be the case that students' self-perceived overlap with their image of a STEM professional will be more predictive of their STEM outcomes, as compared to their self-rated overlap with a set of objective standards for defining a STEM professional (which they may or may not recognize as being important in their pursuit of a STEM career). The reference to a STEM professional also means that the measure is not specific to a particular science, which allows respondents to imagine any STEM professional that they are aspiring to become, across a variety of disciplines.

Although there are clearly drawbacks to using a single-item measure, there are also many advantages to assessing STEM identity in this way. For example, it allows for repeated assessments that are not taxing for the individual being assessed, thereby providing a "snapshot" of the individual's identity at a particular moment, and enabling researchers and teachers to track how students' STEM identity evolves over time, and what experiences foster a stronger identification with STEM. Importantly, the measure does not pre-suppose that one's identity as a STEM professional is fixed, thereby making it possible to observe change in one's identity. The measure is also simple enough to be used with a wide array of age groups (i.e., from children to adults).

The Current Research

The aim of the current research was to provide initial evidence for the validity and reliability of the STEM-PIO-1 as a measure of

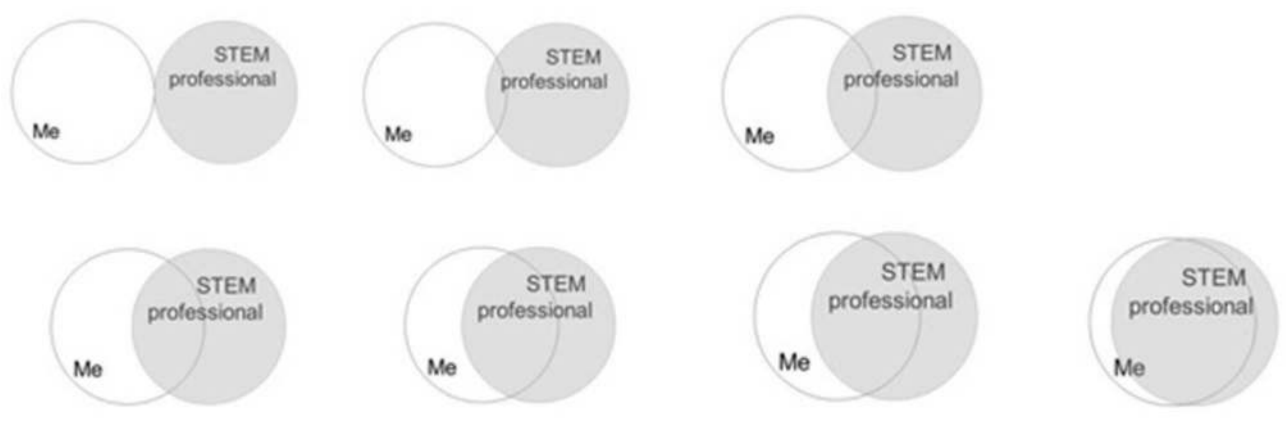

FIGURE 1 | *STEM Professional Identity Overlap Measure*. Participants were instructed to select the picture that best describes the current overlap of the image they have of themselves and their image of what a STEM professional is.

STEM identity. Across three studies, we examined the convergent validity of the measure with an existing measure of STEM identity, the criterion validity by examining its associations with concurrent outcomes for which we expect STEM identity to be able to predict as well as its ability to predict criterion group membership as a STEM major, and its discriminant validity by examining whether it predicts unique variance in relevant outcomes over and above that predicted by centrality measures of STEM identity. We also examined the test-retest reliability of the measure over a 6-month time span, and the inter-item reliability of an expanded four-item version of the measure.

We selected constructs to test the criterion validity of the STEM-PIO-1 based on the perspective of Motivational Intensity Theory (Brehm and Self, 1989; Richter et al., 2016), which states that effort is directed toward a goal, even as it increases in difficulty, as long as the importance of success is sufficiently high. For students who highly identify with STEM, becoming a STEM professional is an idealized state, thereby justifying a high degree of effort. As a consequence, we expected that students more strongly identified with STEM (relative to students who weakly identify with STEM) would have more positive attitudes toward STEM, feel more efficacious in their pursuit of STEM learning, be more likely to engage in agentic behaviors to facilitate their end-goal, and be more likely to persist toward their STEM career goals and therefore report a reduced likelihood of changing their major. We also explored whether STEM identity would be associated with mastery goal orientation (vs. performance goal orientation). Mastery goals reflect an intrinsic desire to develop skills and expertise and are associated with an incremental implicit theory about intelligence, that is, that intelligence is malleable and capable of growth. In contrast, performance goals are simple shows of competence, that are associated with an entity implicit theory about intelligence, that is, that intelligence is a fixed trait that cannot be increased (Dweck, 1996; Elliot and Church, 1997). Given the difficulty of coursework in STEM, and the strong likelihood that students will often struggle to perform at a high level of competence, it is expected that students with performance goals will find other majors more appealing as a means of displaying competence, whereas those with a mastery orientation will be more willing to invest effort in learning, and continue to identify as a STEM professional, even in the face of hardship and reduced performance.

In Study 2, we additionally tested the reliability of the STEM-PIO-1. This was done in two ways. First, we examined the test-retest reliability of the measure across a 6-month time span for a small subset of students. Second, we expanded the measure with three additional items that assessed students' perceived overlap with those aspects of science identity outlined as important by Carlone and Johnson (i.e., competence, performance, and recognition). This multi-item measure allowed us to assess the internal reliability of the measure, and determine whether our measure was capturing the breadth of these important identity elements. Finally, in Study 3, we examined the association between our measure and measures of STEM identity that focus on identity centrality, in order to determine whether something unique was captured by our measure of typicality.

STUDY 1

To provide an initial validation of the single-item *STEM Professional Identity Overlap* (STEM-PIO-1) measure, we administered it to a sample of college and university students, across a variety of STEM and non-STEM majors. We included an existing measure of STEM identity to provide evidence of convergent validity, as well as measures of relevant criteria that should be associated with STEM identity, including attitudes toward STEM, self-efficacy in STEM, agency toward STEM goals, goal orientation, and desire to persist in the STEM major. We also examined the extent to which scores on the STEM-PIO-1 varied as a function of demographic characteristics.

Method

Participants and Procedure

Participants were college and university students in various institutions across the state of Alabama (see **Table 1**). Participants were invited to participate in the study via an email solicitation. Those electing to participate provided written informed consent. Participation required completing an online survey assessing a variety of demographic, academic, and psychological variables. Participation was incentivized via inclusion of participants into a raffle to win one of several gift cards. This study and those that follow were carried out with the institutional review board approval of participating institutions and were conducted in accordance with the 1964 Helsinki declaration and its later amendments.

The sample included students in STEM fields and non-STEM fields. Among the STEM students, there was a sub-sample of students who had recently been accepted into a STEM scholarship program (MAKERS: Making to Advance Knowledge,

TABLE 1 | Descriptive statistics for scholar and control samples in studies 1–3.

	Study 1		Study 2	Study 3
	MAKERS	**Controls**	**Controls**	**Controls**
N	414	62	316	487
Age *M*(*SD*)	19.5 (1.71)	22.9 (6.90)	23.6 (7.16)	21.7 (5.35)
Female	58%	83%	79%	71%
URG	79%	62%	52%	50%
Parental Income (Mdn)	50–75k	50–75k	50–75k	50–75k
Mother Education (Mdn)	B.S./B.A.	A.A./A.S.	B.S./B.A.	B.S./B.A.
Father Education (Mdn)	A.A./A.S.	Technical	B.S./B.A.	A.A./A.S.
Affiliation				
Alabama A&M University	11%	4%	0.3%	3%
Auburn University	29%	1%	3%	28%
Auburn University—Montgomery	6%	66%	41%	32%
Lawson State C.C.	8%	0%	8%	0.4%
Southern Union State C.C.	10%	0%	27%	10.3%
Tuskegee University	35%	29%	20%	26%

URG = racial or ethnic group traditionally underrepresented in STEM, including individuals who self-identified as Black/African-American, American Indian/Alaska Native, Native Hawaiian/Other Pacific Islander, or Hispanic/Latino(a). Technical = Technical training. C.C., Community College.

Excellence, and Recognition in STEM). The MAKERS program is funded by a collaborative S-STEM Grant from the National Science Foundation (NSF), and provides scholarships, academic support, and social support to students majoring in STEM fields (biological, physical, mathematical, geological, and computer and information sciences; engineering; and associated technology areas). However, these students had not yet begun their participation in the MAKERS program, so they were combined with the rest of the sample (descriptive statistics comparing the two samples are provided in **Table 1**). In total, 67 students from the MAKERS program participated in the survey, but five were excluded due to substantial missing data ($n = 62$). The sample of students who were not part of the MAKERS program consisted of 499 participants; however, 67 were excluded due to substantial missing data, and 18 were excluded for being a univariate outlier (i.e., more than three standard deviations above or below the mean) on at least one measure ($n = 414$). The final sample consisted of 476 participants.

Measures

STEM professional identity overlap (STEM-PIO-1)

Students' identification as a STEM professional was assessed with a one-item pictorial scale derived from the measure of interpersonal closeness developed by Aron et al. (1992). Participants were given the following instructions, "*STEM professionals are individuals whose professional activities relate to the STEM fields (Science, Technology, Engineering, or Mathematics). Select the picture that best describes the current overlap of the image you have of yourself and your image of what a STEM professional is.*" Participants selected among a set of seven overlapping circles varying in the degree of overlap: 1 = no overlap and 7 = near complete overlap (see **Figure 1**).

STEM attitudes and identity

Existing measures of science identity and attitudes toward science were adapted to assess STEM identity and attitudes toward STEM (Young et al., 2013). Responses were provided on a scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). STEM identity was assessed with five items, including "*Being a STEM student is an important reflection of who I currently am*." Attitudes toward STEM were assessed with four items, such as, "*In general, I find working on assignments in my STEM courses very interesting*." For students who were not STEM majors, instructions asked them to reflect on the STEM courses they had recently taken in high school or college. Participants were also asked to indicate their current satisfaction with their STEM major, ranging from "*I think I have found my true calling*" to various levels of dissatisfaction (i.e., "*I am not sure this is what I want to do for a living*;" "*I have not enjoyed most of the courses I have taken so far*;" "*I am considering changing majors*"). Responses expressing dissatisfaction were collapsed into a single category and compared to those indicating that their major represents their true calling.

STEM self-efficacy and agency

A subset of six items were adapted from a measure of self-efficacy in biology (Baldwin et al., 1999) to assess self-efficacy in STEM. For example, "I am confident I have the ability to learn the material taught in my STEM courses." Responses were scored on a scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Non-STEM majors were asked to reflect on STEM courses they had recently taken in high school or college. To assess agentic behaviors, participants were asked "How confident are you that you have knowledge of all requirements needed to graduate in your major(s)?" with response options ranging from 1 (*not sure at all*) to 4 (*completely sure*).

Performance and mastery goal orientation

Performance and mastery goal orientations were assessed using a measure adapted by Shell and Husman (2008). Instructions told participants that, "*Students differ in what they want to get out of the courses they take. Use the scale given to rate how important achieving each of the following is for you*." Responses were recorded on a scale ranging from 1 (*very unimportant*) to 5 (*very important*). Performance goal orientation was captured by eight items, for example, "*Remembering enough from the class to impress other people*." Mastery goal orientation was assessed with five items, including, "*Learning new knowledge or skills in the class just for the sake of learning them*."

Results

We first sought to examine the construct validity of the STEM-PIO-1 by examining its associations with measures assessing the same or highly related constructs (**Table 2** presents descriptive data for measured variables). There were moderate associations with Young's et al. (2013) adapted measure of STEM identity [$r_{(476)} = 0.42$, $p < 0.001$], a measure of attitudes toward STEM [$r_{(476)} = 0.39$, $p < 0.001$], and a measure of self-efficacy in STEM [$r_{(476)} = 0.37$, $p < 0.001$]. We then examined whether STEM-PIO-1 would predict goal orientation among STEM majors, with the expectation that students who highly identified with STEM professionals would exhibit greater mastery goal orientation, but not necessarily performance goal orientation. This prediction was partially supported—STEM-PIO-1 was positively associated with an orientation toward mastery goals [$r_{(475)} = 0.14$, $p = 0.002$], and weakly positively associated with performance goal orientation [$r_{(475)} = 0.09$, $p = 0.048$].

To further illustrate the construct validity of the measure, we examined whether STEM-PIO-1 would detect differences in identification with STEM between students majoring in a STEM field vs. those in non-STEM fields. Students were categorized into non-STEM ($n = 162$), soft-STEM ($n = 43$), hard-STEM ($n = 196$), and health ($n = 63$) (the designations of soft and hard STEM were consistent with those proposed by Biglan, 1973). An ANOVA revealed significant differences in STEM-PIO-1 scores across majors, $F_{(3, 460)} = 10.06$, $MSE = 2.81$, $p < 0.001$. Bonferroni *post-hoc* analysis of mean differences (see **Table 3**) indicated that non-STEM majors reported significantly lower STEM-PIO-1 ($M = 3.75$, $SD = 1.71$) than hard-STEM majors ($M = 4.70$, $SD = 1.68$; $d = 0.56$). Thus, the STEM-PIO-1 was sensitive to differences in STEM identification among individuals who are, and are not, currently pursuing a STEM major. We also examined whether STEM-PIO-1 in STEM majors would predict their degree of confidence in knowing the requirements to

TABLE 2 | Descriptive statistics for measured variables in study 1.

	1	2	3	4	5	6	7
STEM-PIO-1							
STEM identity	0.42*						
STEM attitudes	0.39*	0.48*					
STEM Self-efficacy	0.37*	0.38*	0.59*				
STEM agency	0.21*	0.16*	0.12*	0.24*			
Performance goals	0.09*	0.19*	0.15*	0.22*	0.01*		
Mastery goals	0.14*	0.27*	0.35*	0.39*	0.12*	0.29*	
Mean *(SD)*	4.24 (1.73)	3.55 (0.77)	3.55 (0.75)	4.18 (0.66)	3.03 (0.86)	3.38 (0.86)	4.32 (0.52)
Alpha (α)	–	0.74	0.75	0.90	–	0.83	0.76

Sample sizes range from n = 475–476.
$^*p < 0.05$.

graduate for their major. STEM-PIO-1 was positively associated with this index of agency [$r_{(314)} = 0.23$, $p < 0.001$] which is consistent with previous research showing a connection between identity and agency (Herrera et al., 2012).

The relationship between STEM identity and satisfaction with one's STEM major was examined by comparing the STEM-PIO-1 between those students endorsing the statement, "*I think I have found my true calling*" vs. those expressing various levels of dissatisfaction. Among STEM majors, STEM-PIO-1 scores were greater for students who reported a positive view of their STEM major ($M = 4.68$, $SD = 1.61$), relative to those who expressed any level of dissatisfaction with their STEM major [$M = 3.94$, $SD = 1.80$; $t_{(312)} = 3.50$, $p = 0.001$; $d = 0.44$].

We then examined whether scores on the STEM-PIO-1 varied as a function of demographic characteristics. Scores for the STEM-PIO-1 were not correlated with participant age [$r_{(476)} = -0.01$, $p = 0.760$], parental income [$r_{(367)} = 0.05$, $p = 0.352$], mother's education [$r_{(458)} = 0.04$, $p = 0.391$], or father's education [$r_{(430)} = -0.004$, $p = 0.926$]. Scores for the STEM-PIO-1 also did not differ between men ($M = 4.35$, $SD = 1.64$) and women ($M = 4.21$, $SD = 1.76$), $t_{(474)} = -0.72$, $p = 0.475$; $d = 0.08$, even when restricting the analysis to hard-STEM majors. STEM-PIO-1 also did not vary as a function of whether the individual is part of a racial or ethnic group that is typically underrepresented in STEM ($M = 4.30$, $SD = 1.75$) or a group that is not typically underrepresented ($M = 4.19$, $SD = 1.69$), $t_{(466)} = 0.64$, $p = 0.523$; $d = 0.06$, regardless of major.

STUDY 2

The results from Study 1 provide preliminary evidence for the validity of the STEM-PIO-1. It displayed moderate association with an adapted self-report measure of STEM identity (Young et al., 2013), and was positively associated with agency and self-efficacy within the STEM major, as well as an intrinsic motivation to pursue academic goals. However, as a single-item measure, it is difficult to ascertain its reliability, as well as the extent to which a single-item measure can capture meaningful aspects of one's STEM identity. To address these issues, a second study was conducted in order to test the reliability of a multi-item measure of STEM professional identity overlap. In particular, the STEM-PIO-1 measure from Study 1 was adapted to measure the specific components of STEM identity presented by Carlone and Johnson (2007): competence, performance, and recognition. These new items were included alongside the original measure to examine how strongly they converge, and to assess the reliability of the total set of items. We also examined the test-retest reliability of the original STEM-PIO-1 with a small subset of our sample that overlapped with Study 1. Finally, we sought to replicate the findings from Study 1, using both the single-item measure, and the new composite measure.

Method

Participants and Procedure

Solicitation for participation and procedure was identical to that of Study 1 with the exception that students who identified as a member of the MAKERS scholarship program, or who failed to indicate their status, were excluded from the analyses presented here ($n = 90$). This was done to prevent overlap in participants between Study 1 and Study 2 (except to examine test-retest reliability), and because at this time point the MAKERS were involved in the interventions offered as part of that program. Of the remaining sample ($n = 377$), 35 were excluded for being a univariate outlier, and 26 were excluded for failing to complete at least one item assessing STEM-PIO. The final sample consisted of 316 participants. The average age was 23.59 ($SD = 7.16$); 79% were female; 52% were members of under-represented groups in STEM (48% African American); median combined parental income was 50–75,000 k; median education for both mothers and fathers was a bachelor's degree. As in Study 1, participants were drawn from colleges and universities in the state of Alabama (see **Table 1** for sample descriptive statistics).

Measures

The same measures from Study 1 were included in Study 2, with two changes. The STEM-PIO-1 measure from Study 1 was complemented with three additional items to assess specific facets of STEM identity. The overlapping circles used as the response scale remained the same, with changes made only to the

TABLE 3 | Differences in STEM-PIO by major category.

	Study 1		Study 2				Study 3			
	STEM-PIO-1		STEM-PIO-1		STEM-PIO-4		STEM-PIO-1		STEM-PIO-4	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Non-STEM	3.75[a]	1.71	3.42[a]	1.88	3.69[a]	1.58	2.70[a]	1.61	2.80	1.36
Soft-STEM	3.95[ab]	1.70	3.44[ab]	1.58	3.60[ab]	1.49	3.28[ab]	2.08	3.73[a]	1.60
Hard-STEM	4.70[b]	1.68	4.61[b]	1.77	4.39[b]	1.35	4.11[c]	1.61	4.15[a]	1.37
Health	4.33[ab]	1.56	4.35[b]	1.80	4.36[b]	1.60	4.09[bc]	1.69	4.23[a]	1.55

Means within columns that share a superscript are not significantly different at $p < 0.05$ using the Bonferroni post-hoc comparison.

instructions. To assess *competence* in STEM, participants were asked to "Select the picture that best describes the extent to which your knowledge of STEM concepts matches that of a STEM professional." To assess *performance* in STEM, participants were asked to "Select the picture that best describes the extent to which your capacity to use STEM skills in a public setting matches that of a STEM professional." To assess *recognition* in STEM, participants were asked to "Select the picture that best describes the extent to which you think others (such as your STEM professors) see your identity as overlapping with a STEM professional." These items were used to create a composite four-item scale.

Participants were again asked to indicate their current satisfaction with their STEM major, but the option "*I think I have found my true calling*" was changed to "*I like this major and will probably not change it*" in order to provide an option that indicates satisfaction but is not imbued with excessive emotional content. The other response options were unchanged and collapsed into a single category indicating dissatisfaction with their major.

Results

A full reporting of descriptive statistics is provided in **Table 4**. The new composite measure, STEM-PIO-4, exhibited good inter-item reliability, $\alpha = 0.87$, with an average inter-item correlation of $r = 0.62$. Each of the items assessing a specific facet of STEM identity were strongly positively associated with the original single-item measure: competence, $r_{(316)} = 0.68$, $p < 0.001$; performance, $r_{(316)} = 0.58$, $p < 0.001$; recognition, $r_{(316)} = 0.59$, $p < 0.001$. It was also possible to examine the test-retest reliability of the STEM-PIO-1 given that there was a small subset of participants in this study who also participated in Study 1 ($n = 11$; these individuals were all scholars in the MAKERS program, and were therefore excluded from all other analyses presented here). The correlation between scores at the first assessment and the second assessment was $r_{(11)} = 0.75$, $p = 0.007$, indicating good reliability across an ∼6-month time span (caution is warranted in interpreting the effect sizes of the coefficients given the small sample of participants). The gender identity measure developed by Tropp and Wright (2001) using the same method of overlapping circles displayed a test-retest reliability correlation of $r = 0.76$, $p < 0.001$, over a shorter time-span (1–3 weeks).

We then compared the construct validity of the single-item (STEM-PIO-1) and four-item (STEM-PIO-4) identity measures. The two measures displayed correlations of similar magnitude predicting convergent constructs: Young et al.'s measure of STEM identity [STEM-PIO-1: $r_{(316)} = 0.28$, $p < 0.001$; STEM-PIO-4: $r_{(316)} = 0.28$, $p < 0.001$], attitudes toward STEM [STEM-PIO-1: $r_{(316)} = 0.40$, $p < 0.001$; STEM-PIO-4: $r_{(316)} = 0.41$, $p < 0.001$], self-efficacy in STEM [STEM-PIO-1: $r_{(316)} = 0.39$, $p < 0.001$; STEM-PIO-4: $r_{(316)} = 0.43$, $p < 0.001$], and mastery goal orientation [STEM-PIO-1: $r_{(316)} = 0.21$, $p < 0.001$; STEM-PIO-4: $r_{(316)} = 0.24$, $p < 0.001$].

A valid measure of STEM identity should also be able to differentiate between students majoring in a STEM field and students majoring in non-STEM fields. As in Study 1, student majors were classified into (1) non-stem, $n = 101$, (2) soft-STEM, $n = 18$, (3) hard-STEM, $n = 103$, and (4) health, $n = 72$. An ANOVA revealed a significant difference among the mean STEM-PIO-4 scores between groups, $F_{(3,\ 290)} = 5.15$, $MSE = 2.26$, $p = 0.002$, as well as the STEM-PIO-1 scores, $F_{(3,\ 290)} = 8.81$, $MSE = 3.25$, $p < 0.001$. *Post-hoc* analyses (see **Table 3**) revealed that STEM identity was significantly lower among non-STEM majors relative to hard-STEM and health majors. Soft-STEM majors did not differ significantly from any group.

Students who are highly identified as a STEM professional should engage in actions to facilitate the realization of that profession. Consistent with this prediction, students' STEM-PIO-1 scores were positively associated with their degree of confidence in knowing the requirements to graduate [STEM-PIO-4: $r_{(316)} = 0.24$, $p < 0.001$; STEM-PIO-1: $r_{(316)} = 0.14$, $p = 0.016$]. Those who strongly identified as a STEM professional should also express a lower likelihood of changing their major. To examine this, non-STEM majors were excluded. Only a small proportion of students expressed any degree of dissatisfaction with their major (24 of 193; 12%). STEM-PIO was not significantly associated with satisfaction [STEM-PIO-4: $t_{(191)} = 1.72$, $p = 0.087$; STEM-PIO-1: $t_{(191)} = 1.19$, $p = 0.237$], but the pattern of means was in the predicted direction—those who were satisfied with their major indicated higher STEM identification [STEM-PIO-4: $M = 4.37$, $SD = 1.46$; STEM-PIO-1: $M = 4.46$, $SD = 1.78$] relative to those who expressed some degree of dissatisfaction with their major (STEM-PIO-4: $M = 3.82$, $SD = 1.50$, $d = 0.37$; STEM-PIO-1: $M = 4.00$, $SD = 1.79$, $d = 0.26$).

We then examined whether STEM-PIO varied as a function of demographic characteristics (across all major groups): STEM-PIO was not significantly associated with participant age (STEM-PIO-4: $r_{(315)} = 0.07$, $p = 0.220$; STEM-PIO-1: $r_{(315)} = 0.07$,

TABLE 4 | Descriptive statistics for measured variables in study 2.

	1	2	3	4	5	6	7	8	9	10	11
STEM-PIO-1											
STEM-PIO-4	0.85*										
STEM competence	0.68*	0.86*									
STEM performance	0.58*	0.84*	0.66*								
STEM recognition	0.59*	0.83*	0.59*	0.62*							
STEM identity	0.28*	0.28*	0.17*	0.23*	0.25*						
STEM attitudes	0.40*	0.41*	0.36*	0.31*	0.32*	0.50*					
STEM self-efficacy	0.39*	0.43*	0.38*	0.38*	0.31*	0.34*	0.56*				
STEM agency	0.14*	0.24*	0.17*	0.24*	0.26*	0.11	0.17*	0.35*			
Performance goals	0.05	0.04	0.06	−0.03	0.04	0.10	0.00	0.16*	0.10		
Mastery goals	0.21*	0.24*	0.21*	0.19*	0.19*	0.18*	0.32*	0.37*	0.05	0.11	
Mean (*SD*)	4.03 (1.87)	4.05 (1.54)	3.86 (1.72)	4.26 (1.83)	4.05 (1.89)	3.45 (0.72)	3.45 (0.76)	4.19 (0.65)	3.09 (0.87)	3.05 (0.70)	4.36 (0.49)
Alpha (α)	–	0.87	–	–	–	0.70	0.75	0.91	–	0.80	0.74

Sample size for all correlations n = 316.
$^*p < 0.05$.

$p = 0.245$], parental income [STEM-PIO-4: $r_{(271)} = 0.03$, $p = 0.588$; STEM-PIO-1: $r_{(271)} = 0.08$, $p = 0.213$], mother's education [STEM-PIO-4: $r_{(192)} = 0.001$, $p = 0.988$; STEM-PIO-1: $r_{(192)} = 0.05$, $p = 0.461$], or father's education [STEM-PIO-4: $r_{(161)} = -0.09$, $p = 0.282$; STEM-PIO-1: $r_{(161)} = 0.02$, $p = 0.828$]. Scores for STEM-PIO did not differ significantly between the sexes [STEM-PIO-4: $t_{[313]} = 1.83$, $p = 0.068$; STEM-PIO-1: $t_{[313]} = 1.68$, $p = 0.095$], though the pattern was such that men reported higher STEM identity than did women. As **Table 5** indicates, this difference was driven primarily by sex differences in perceived overlap for STEM performance. However, when the analysis was restricted to only hard-STEM majors, the overall effect was completely erased, if not reversed, such that women tended to report higher STEM identity, particularly for the facet of recognition, though no differences were statistically significant.

Lastly, we compared STEM-PIO as a function of whether the student is part of an ethnic or racial group that is typically underrepresented in STEM (URGs). Results indicated no significant differences for the STEM-PIO-4 [$t_{(308)} = 1.75$, $p = 0.081$] or STEM-PIO-1 [$t_{(308)} = 1.29$ $p = 0.198$], although the pattern was such that URGs reported *higher* STEM identity overlap than did non-URGs. As shown in **Table 6**, when the facets of STEM-PIO were examined separately, a significant difference was obtained for competence [$t_{(308)} = 2.12$, $p = 0.034$]. When restricting the analysis to hard-STEM majors only, the overall differences between groups were similar, but none of these differences were statistically significant.

STUDY 3

The results of Studies 1 and 2 provide preliminary evidence that the STEM-PIO-1 and STEM-PIO-4 may be sufficiently reliable and valid measures of STEM identity, and that the STEM-PIO-1 provides good coverage of elements considered essential to the development of STEM identity (competence, performance, and recognition). A key issue left unaddressed by these studies is that both measures assess STEM identity in terms of students' perceived overlap with STEM professionals, rather than the importance or centrality of STEM to their identity. As a result, our measure can be best described as a measure of STEM typicality such that students are imagining a prototypical scientist and determining how similar they are to that prototype. This method was selected owing to the possibility that under-represented groups in STEM might experience a particularly large gap in perceived typicality owing to stereotypes of STEM professionals as White men. Given this, a large perceived discrepancy may be a powerful predictor of reduced persistence in STEM.

However, an alternative way to assess STEM identity is via centrality or importance of the identity to the individual (Leach et al., 2008). Typicality and centrality may be orthogonal, or only weakly related, constructs. For example, some students may highly value STEM as an important and central part of their identity, but be aware that they have not yet mastered STEM concepts to a degree that would allow them to feel a sense of typicality with STEM professionals. However, because students tend to over-estimate their typicality with STEM professionals (Nadelson et al., 2015), the two constructs may be strongly associated. Distinguishing between these possibilities is important, as it will provide information about whether the STEM-PIO-1 captures unique variance in STEM identity beyond what is assessed by STEM identity centrality, therefore providing an index of its discriminant validity. To examine this, we conducted a third study in which participants completed the STEM-PIO measures of typicality along with a new STEM-PIO item assessing centrality, as well as a longer, adapted measure of STEM centrality.

Method

Participants and Procedure. Solicitation for participation and procedure was identical to that of Study 2. Students were

TABLE 5 | Differences in STEM identity by sex.

	STUDY 2 ($n = 310$)			STUDY 3 ($n = 487$)		
All majors	**Men**	**Women**	***d***	**Men**	**Women**	***d***
STEM-PIO-1	4.36 (1.83)	3.93 (1.87)	0.23	3.98 (1.66)	3.69 (1.79)	0.17
STEM-PIO-4	4.36 (1.41)	3.97 (1.57)	0.25	4.20 (1.44)	3.74 (1.53)	0.30*
STEM competence	4.14 (1.69)	3.78 (1.72)	0.21	3.92 (1.62)	3.51 (1.63)	0.25*
STEM performance	4.68 (1.75)	4.14 (1.84)	0.29*	4.28 (1.70)	3.99 (1.80)	0.16
STEM recognition	4.24 (1.83)	4.00 (1.91)	0.13	4.39 (1.73)	3.71 (1.85)	0.37*
STEM-C				4.38 (1.69)	3.98 (1.77)	0.23*
CSES[a]				5.06 (0.80)	4.88 (0.83)	0.22*
	Study 2 ($n = 102$)			**Study 3 ($n = 252$)**		
Hard-STEM majors	**Men**	**Women**	***d***	**Men**	**Women**	***d***
STEM-PIO-1	4.27 (1.88)	4.74 (1.70)	−0.26	4.35 (1.49)	3.94 (1.68)	0.25*
STEM-PIO-4	4.23 (1.32)	4.46 (1.37)	−0.17	4.50 (1.31)	3.90 (1.36)	0.44*
STEM competence	4.18 (1.76)	4.07 (1.52)	0.07	4.17 (1.51)	3.55 (1.42)	0.42*
STEM performance	4.58 (1.56)	4.46 (1.68)	0.07	4.63 (1.64)	4.14 (1.63)	0.30*
STEM recognition	3.88 (1.73)	4.55 (1.75)	−0.38	4.70 (1.57)	4.01 (1.81)	0.40*
STEM-C				4.74 (1.53)	4.32 (1.63)	0.26*
CSES[b]				5.23 (0.76)	5.05 (0.84)	0.23

M(SD). [a]$n = 451$; [b]$n = 236$.
$p < 0.05$ via independent samples t-test.

excluded from analysis if they were a member of the MAKERS scholarship program, were a univariate outlier (i.e., more than three SDs above or below the mean; $n = 40$), had substantial missing data ($n = 295$), failed to complete at least one of the items assessing STEM identity ($n = 25$), did not report their age, or were not 18 years of age or older ($n = 4$). The final sample consisted of 487 participants. The average age was 21.69 ($SD = 5.35$); 71% female; 50% were members of groups under-represented in STEM (43% African American); median combined parental income was 50–75,000 k; median education for mothers was a bachelor's degree, and an associate's degree for fathers. Participants were drawn from colleges and universities in the state of Alabama (see **Table 1**).

Measures

The same STEM-PIO measures from Study 2 were included with an additional item assessing STEM centrality (STEM-C). The new item applied the same response format with overlapping circles, with changes made only to the instructions. Participants were asked to "Select the picture that you feel best represents your level of identification with STEM professionals as a group." The Collective Self-Esteem Scale (CSES; Luhtanen and Crocker, 1992) was also included (adapted to be relevant to STEM identity) in order to determine whether the STEM-PIO typicality measures would predict an established measure of the value and importance of a group identity. The CSES contains subscales assessing membership esteem (e.g., "I am a worthy member of the STEM groups I belong to"), public collective self-esteem (e.g., "Overall, my STEM groups are considered good by others"), private collective self-esteem (e.g., "In general, I'm glad to be a member of the STEM groups I belong to"), and importance to identity (e.g., "The STEM groups I belong to are an important reflection of who I am"). The STEM identity measure by Young et al. (2013) was included again (which also serves as a measure of STEM centrality), as were the measures of STEM attitudes, agency, efficacy, and the assessment of mastery vs. performance goals.

Results

Descriptive statistics for key measured variables are provided in **Table 7**. STEM-PIO typicality measures were moderately correlated with identity measures based on centrality. The new STEM-C item was strongly positively correlated with the STEM-PIO-1 [$r_{(487)} = 0.72$, $p < 0.001$] and STEM-PIO-4 [$r_{(487)} = 0.71$, $p < 0.001$]. Additionally, the STEM-PIO measures were positively correlated with each facet of collective self-esteem as it pertained to one's membership in STEM groups, including the CSES total score [STEM-PIO-1: $r_{(451)} = 0.39$, $p < 0.001$; STEM-PIO-4: $r_{(451)} = 0.36$, $p < 0.001$], as well as Young's et al. (2013) measure of STEM identity [STEM-PIO-1: $r_{(487)} = 0.38$, $p < 0.001$; STEM-PIO-4: $r_{(487)} = 0.36$, $p < 0.001$].

STEM-PIO measures also displayed similarly positive associations with key correlates of STEM identity as compared to the STEM-C and CSES. For example, each were positively associated with STEM attitudes [STEM-PIO-1: $r_{(487)} = 0.38$, $p < 0.001$; STEM-PIO-4: $r_{(487)} = 0.36$, $p < 0.001$; STEM-C: $r_{(487)} = 0.39$, $p < 0.001$; CSES: $r_{(451)} = 0.36$, $p < 0.001$], STEM self-efficacy [STEM-PIO-1: $r_{(487)} = 0.31$, $p < 0.001$; STEM-PIO-4: $r_{(487)} = 0.41$, $p < 0.001$; STEM-C: $r_{(487)} = 0.31$, $p < 0.001$; CSES: $r_{(451)} = 0.40$, $p < 0.001$], confidence in knowing the

TABLE 6 | Differences in STEM identity by URG membership.

	Study 2 (n = 310)			Study 3 (n = 468)		
All Majors	**URGs**	**Non-URGs**	***d***	**URGs**	**Non-URGs**	***d***
STEM-PIO-1	4.12 (1.81)	3.85 (1.90)	0.15	3.89 (1.80)	3.71 (1.70)	0.10
STEM-PIO-4	4.18 (1.45)	3.87 (1.63)	0.20	3.98 (1.53)	3.81 (1.49)	0.11
STEM competence	4.02 (1.63)	3.61 (1.77)	0.24*	3.78 (1.70)	3.52 (1.55)	0.16
STEM performance	4.40 (1.85)	4.09 (1.80)	0.17	4.18 (1.80)	4.03 (1.74)	0.08
STEM recognition	4.16 (1.86)	3.93 (1.94)	0.12	3.97 (1.84)	3.88 (1.85)	0.05
STEM-C				4.09 (1.78)	4.15 (1.73)	−0.03
CSES[a]				4.96 (0.85)	4.93 (0.80)	0.04
	Study 2 (n = 102)			**Study 3 (n = 243)**		
Hard-STEM majors	**URGs**	**Non-URGs**	***d***	**URGs**	**Non-URGs**	***d***
STEM-PIO-1	4.73 (1.61)	4.26 (2.05)	0.27	4.35 (1.62)	3.93 (1.60)	0.26*
STEM-PIO-4	4.50 (1.29)	4.11 (1.47)	0.29	4.30 (1.30)	4.03 (1.42)	0.20
STEM competence	4.18 (1.55)	3.94 (1.69)	0.16	4.03 (1.49)	3.61 (1.47)	0.29*
STEM performance	4.56 (1.62)	4.35 (1.68)	0.13	4.46 (1.59)	4.27 (1.71)	0.11
STEM recognition	4.52 (1.75)	3.90 (1.74)	0.35	4.42 (1.69)	4.20 (1.82)	0.13
STEM-C				4.59 (1.61)	4.45 (1.60)	0.09
CSES[b]				5.19 (0.82)	5.10 (0.79)	0.11

M(SD). [a]*n = 433;* [b]*n = 227.*
*$p < 0.05$ via independent samples t-test.

requirements to graduate [STEM-PIO-1: $r_{(484)} = 0.24$, $p < 0.001$; STEM-PIO-4: $r_{(484)} = 0.28$, $p < 0.001$; STEM-C: $r_{(484)} = 0.25$, $p < 0.001$; CSES: $r_{(448)} = 0.20$, $p < 0.001$], and mastery goals [STEM-PIO-1: $r_{(434)} = 0.19$, $p < 0.001$; STEM-PIO-4: $r_{(434)} = 0.17$, $p = 0.001$; STEM-C: $r_{(434)} = 0.16$, $p = 0.001$; CSES: $r_{(434)} = 0.30$, $p < 0.001$], but not performance goals [STEM-PIO-1: $r_{(434)} = -0.04$, $p = 0.420$; STEM-PIO-4: $r_{(434)} = 0.01$, $p = 0.915$; STEM-C: $r_{(434)} = 0.004$, $p = 0.930$; with the exception of CSES: $r_{(434)} = -0.14$, $p = 0.004$]. Overall, these patterns were relatively consistent when the analysis was conducted separately by major category (non-STEM, soft-STEM, hard-STEM, and Health).

To determine whether the STEM-PIO measures are explaining the same variance in these outcomes as the centrality measures of identity, we conducted a series of hierarchical multiple regression analyses in which the CSES was entered as the first predictor, followed by the STEM-PIO-1 in the second step. This was repeated for each of the key outcome variables. Overall, the change in R^2 from the addition of the STEM-PIO-1 indicated that the STEM-PIO-1 is predicting unique variance in key outcomes, beyond what is predicted by the CSES centrality measure of STEM identity. Indeed, its addition increased the variability explained in self-efficacy by 3.2% [$F_{(1, 448)} = 17.73$, $p < 0.001$], in STEM attitudes by 6.4% [$F_{(1, 448)} = 37.20$, $p < 0.001$], and in agency (i.e., knowing requirements to graduate) by 2.6% [$F_{(1, 445)} = 12.22$, $p = 0.001$]. However, it produced only a 0.6% (*n.s.*) increase in the variance explained of mastery goal orientation [$F_{(1, 431)} = 2.86$, $p = 0.091$].

As in Studies 1 and 2, we next focused on the validation of the STEM-PIO measures.

Both were able to differentiate between students majoring in STEM fields vs. non-STEM fields (non-STEM, $n = 94$; soft-STEM, $n = 36$; hard-STEM, $n = 252$; health, $n = 105$). An ANOVA revealed a significant difference among the mean STEM-PIO-1 scores between groups, $F_{(3, 483)} = 18.61$, $MSE = 2.78$, $p < 0.001$, as well as the STEM-PIO-4 scores, $F_{(3, 483)} = 23.22$, $MSE = 2.03$, $p < 0.001$. *Post-hoc* analyses (see **Table 3**) revealed that STEM identity was significantly lower among non-STEM majors relative to most of the other major groups. Stronger identification with STEM (among STEM majors) was also associated with agency in that highly identified students were more likely to report feeling confident that they know the requirements to graduate [STEM-PIO-1: $r_{(391)} = 0.27$, $p < 0.001$; STEM-PIO-4: $r_{(391)} = 0.34$, $p < 0.001$]. Strongly identified STEM majors also appear to be more likely to persist in their major. In particular, STEM majors who reported that they like their major and probably will not change it had significantly higher STEM-PIO scores than those who indicated varying degrees of dissatisfaction with their STEM major [STEM-PIO-1: $t_{(391)} = 3.14$, $p = 0.002$, $d = 0.46$; STEM-PIO-4: $t_{(391)} = 2.89$, $p = 0.004$, $d = 0.43$].

Next, we examined whether the STEM-PIO measures varied as a function of demographic characteristics. Neither of the measures produced a significant association with student age [STEM-PIO-1: $r_{(487)} = -0.02$, $p = 0.630$; STEM-PIO-4: $r_{(487)} = -0.02$, $p = 0.748$], father's education [STEM-PIO-1: $r_{(438)} = 0.01$, $p = 0.824$; STEM-PIO-4: $r_{(438)} = 0.05$, $p = 0.266$], or mother's education [STEM-PIO-1: $r_{(462)} = 0.05$, $p = 0.320$; STEM-PIO-4: $r_{(462)} = 0.03$, $p = 0.510$]. Weak positive associations were found for both measures with parental income [STEM-PIO-1: $r_{(401)} = 0.10$, $p = 0.049$; STEM-PIO-4: $r_{(401)} = 0.14$, $p = 0.007$]. Men tended to report higher STEM identity scores than did women [STEM-PIO-1: $t_{(485)} = 1.67$, $p = 0.096$; STEM-PIO-4: $t_{(485)} =$

TABLE 7 | Descriptive statistics for measured variables in study 3.

	1	2	3	4	5	6	7	8	9	10	11	12	13
STEM-PIO-1													
STEM-PIO-4	0.69*												
STEM competence	0.62*	0.87*											
STEM performance	0.59*	0.89*	0.70*										
STEM recognition	0.59*	0.85*	0.58*	0.61*									
STEM centrality	0.72*	0.71*	0.61*	0.61*	0.62*								
CSES	0.39*	0.36*	0.29	0.29*	0.36*	0.43*							
STEM identity	0.38*	0.36*	0.28*	0.30*	0.35*	0.40	0.47*						
STEM attitudes	0.38*	0.36*	0.27*	0.28*	0.38*	0.39*	0.41*	0.43*					
STEM self-efficacy	0.31*	0.41*	0.37*	0.33*	0.37*	0.31*	0.40*	0.29*	0.49*				
STEM agency	0.24*	0.28*	0.24*	0.22*	0.26*	0.25*	0.20*	0.05	0.24*	0.42*			
Performance goals	–0.04	0.01	0.00	0.00	0.01	0.00	–0.14*	0.06	–0.07	0.06	0.05		
Mastery goals	0.19*	0.17*	0.15*	0.18*	0.10*	0.16*	0.30*	0.22*	0.34*	0.33*	0.15*	0.02	
Mean (*SD*)	3.77 (1.76)	3.87 (1.52)	3.63 (1.64)	4.08 (1.78)	3.91 (1.84)	4.09 (1.75)	4.93 (0.83)	3.51 (0.74)	3.49 (0.70)	4.12 (0.62)	3.00 (0.83)	3.06 (0.70)	4.30 (0.53)
Alpha (α)	–	0.86	–	–	–	–	0.88	0.75	0.74	0.88	–	0.81	0.76

Sample sizes vary from $n = 434$ to 487.
$^*p < 0.05$.

3.03, $p = 0.003$], an effect that was strongest among hard-STEM majors (see **Table 5**).

Lastly, we compared STEM-PIO as a function of whether the student is part of a racial or ethnic group that is typically underrepresented in STEM (URGs). With the full sample, no comparisons reached statistical significance. When the analysis was repeated, broken down by major (see **Table 6**), a significant difference was obtained among hard-STEM majors on the STEM-PIO-1, $t_{(241)} = 2.02$, $p = 0.045$, and the competence facet of STEM-PIO-4, $t_{(241)} = 2.24$, $p = 0.026$. As in Study 2, the pattern was such that URGs reported stronger STEM identity compared to non-URGs.

DISCUSSION

Science identity has recurrently emerged as an important concept in the understanding of interest, motivation, and persistence in STEM. STEM identity has been defined as a dynamic part of an individual's identity, and it is as much a personal construct as it is a social construct that reflects the individual's sociocultural context (e.g., Herrera et al., 2012). Here, we take the perspective that each individual student has a vision of what a STEM professional is, a *possible self,* that he or she may be hoping to achieve (*cf.* Markus and Nurius, 1986). The STEM-PIO-1 allows students to compare their current state with that ideal state (their vision of a STEM professional), and assess the overlap they perceive between the two.

The results of our research suggest that the STEM-PIO-1 may be a sufficiently valid and reliable measure of STEM identity. The STEM-PIO-1 displayed moderate convergent, criterion, and discriminant validity, and it demonstrated good test-retest reliability in a small sample. Although we might expect stronger convergent associations, it is important to note that the comparison measures we used assess identity *centrality*, whereas our measure is based on identity *typicality*. Additionally, the comparison measures focus on one's identity as a current STEM student, rather than as a future STEM professional. These factors, along with the markedly different response formats, likely contribute to moderate associations ranging between $r =$ 0.30 and 0.40. However, it is also important for future research to think about the different meanings of STEM identity when conceptualized as typicality vs. centrality, and which is more important for the outcomes of interest to researchers. Although in the current research, the predictive power of identity centrality vs. typicality measures was quite similar, it is likely that for some outcomes or some populations, their power may vary.

The findings presented here provide some evidence for the breadth of content captured by the STEM-PIO-1 via its strong convergence with the items of the STEM-PIO-4. These items were designed to assess elements of STEM identity revealed to be important by qualitative research (Carlone and Johnson, 2007), specifically the perceived overlap with competence, performance, and recognition of STEM professionals. However, it is important to note that some of this convergence may be due to shared method variance, as all items used the same pictorial response scale, which may lead participants to respond more consistently than they would using a different response scale.

The STEM-PIO-1 was also moderately associated with key outcomes that would be expected to follow from students being highly identified with STEM. Consistent with other research documenting the potential benefits of fostering strong science identity, our research suggests that students strongly identified with STEM have more positive attitudes toward STEM, feel more efficacious in their STEM work, engage in agentic behavior to achieve their STEM goals, are more likely to be motivated by mastery goals, and are more satisfied with their major. Interestingly, the STEM-PIO-1 did not consistently vary as a function of demographic variables, as some past research has shown (e.g., Syed et al., 2011; Hazari et al., 2013). One reason for this may be that we have a very diverse sample, with students of various majors drawn from institutions that vary substantially in their sociocultural and economic factors. This can create a noisier sample than one in which all participants are from the same university and a single major. For example, being Black at an HBCU vs. a predominantly White university can mean very different things for one's sense of identification with the STEM profession. Thus, the effect of demographic variables may be important, but in context, and at the intersection of other identities. Our research was not set up to assess these nuances, but it will be important to improve our understanding of these variables with larger samples situated in particular contexts, that may allow for a clearer picture to emerge.

Of course, a key limitation of this research is that it only examines a snapshot of STEM identity at a particular timepoint. It is not clear that STEM identity is causally responsible for these positive outcomes. Yet, this is a key benefit of this single-item measure because future longitudinal research could efficiently use it to track the development of STEM identity over time. The development of science identity is associated with many factors. Most children have positive attitudes toward science. However, during adolescence—a crucial time period for making long-term academic decisions (Archer et al., 2010)—interest in science declines for many students. This corresponds with a sharp decline in students' intentions to major in STEM fields following high school (Berryman, 1983). Depictions of scientists in the media can strongly influence identity development by producing an image of what a STEM professional should be (Steinke, 2017). We propose that, by virtue of being a single-item pictorial measure, the STEM-PIO-1 can be used repeatedly to assess the changes in identification with STEM that can occur as a student progresses through his or her educational track. For example, London et al. (2011) used a similar adaptation of Aron's et al. (1992) Inclusion of Other in the Self measure to assess women's compatibility between their gender and their major in a daily-diary study that was proposed to be an ecologically-valid test of the continuously changing relationship between such compatibility and STEM engagement.

Allowing each individual to compare themselves to their image of a STEM professional leaves open the question of *what* that ideal image *is*, or whether the individual's image is consistent with the socially accepted view of a STEM professional. This may be especially important when assessing individuals from groups traditionally underrepresented in STEM, as their motivations for pursuing STEM and their idea of what a STEM career will look like, may differ from the broader population (Carlone and Johnson, 2007). Additionally, popular depictions of scientists and people who are interested in science change dramatically over time and across contexts, with popular media depictions of scientists potentially impacting young individuals' developing identities (Steinke, 2017). Furthermore, interest in science is strongly determined by the opportunities to explore science that students experience during their K-12 years, and academic confidence in science classes may affect the development of science interest (Astin, 1993). Thus, one could anticipate that the extent to which any given student views a large overlap between the self and a STEM professional will be at least partially determined by the social context and educational opportunities that student has experienced.

Groups under-represented in STEM are also those groups with potentially lower access to rigorous educational opportunities in science (Oakes, 1992), as well as fewer opportunities to be recognized for science achievements. Some individuals are able to redefine what a scientist is to fit with their own values and experiences. For example, the women interviewed by Carlone and Johnson (2007) saw science as a useful tool for pursuing their desire to help others. This more stereotypically feminine goal may contradict the more masculine norms that pervade many scientific disciplines and which is commonly depicted in the media (Steinke, 2017). Future work should examine the overlap that identity has with the domains of competence, performance, and recognition that were proposed by Carlone and Johnson (2007) and Herrera et al. (2012). This could potentially be quite important because it would allow researchers to examine whether STEM identity in groups traditionally under-represented in STEM is especially likely to be hindered by a failure to receive—or at least perceive—recognition from others.

Although we provide a range of evidence in favor of the validity and reliability of the STEM-PIO-1, it is important to note that, overall, these associations are moderate in their magnitude, likely reflecting the tradeoff between the simplicity of our single-item measure and its power to strongly predict outcomes. Some researchers may prefer to use the STEM-PIO-4 for this reason, whereas others may place a premium on having the shortest and simplest measure possible. Importantly, the STEM-PIO-4 includes the STEM-PIO-1, thereby still promoting consistency in measurement across studies, regardless of which measure is used.

There are many additional pieces of evidence that are necessary to examine before confidence in the STEM-PIO-1 can be achieved. The test-retest reliability of the measure was examined only for a small sample of select students, and may not be generalizable to other populations. Future research requires larger samples in a greater diversity of contexts, at different intervals of re-testing. The 6-month time interval used here may capture real change in student's identity owing to their educational experiences, whereas shorter intervals may provide a better estimate of the error contained in the measure. An examination of how STEM-PIO-1 stability changes for people in different stages of their path to becoming a STEM professional will contribute to the validity of the measure. For example, we might expect adolescents to display less stability than older students, first year students to show less stability than later-year students, and young professionals to show less stability than seasoned professionals.

Verification that the STEM-PIO-1 displays convergent, discriminant, and criterion validity in other populations is also crucial. Our samples across the three studies reported here are diverse, with students of various majors being drawn from institutions that vary substantially in their sociocultural and economic factors. This is a strength, but also a limitation as we have limited power within each of these subgroups to compare validity. It is important to examine the influence of these variables with larger samples situated in particular contexts, which may allow for a clearer picture of the generalizability of the validity of the STEM-PIO-1 to emerge. Future research should also examine other types of validity evidence not assessed here. For example, the content validity of the STEM-PIO-1 could be assessed via review of the measure by STEM experts. Along similar lines, qualitative data on students' perception of the measure (e.g., what they are envisioning when they consider a "STEM professional") would be useful to feel confident that the measure is capturing the intended construct. Convergent validity can be additionally examined via a comparison of self- and other-reports (e.g., from teachers or parents). Predictive validity should also be assessed, particularly with objective longitudinal outcomes, such as graduation rates, admission to graduate programs, and employment in a STEM career.

CONCLUSIONS

Research across STEM disciplines has converged on the idea that students' science identity is an important determinant of persistence in STEM fields. Yet conclusions based on this research are difficult to quantify due to the fact that much of the research is either qualitative in nature or uses novel quantitative measures, most of which have not been properly validated. Here, we offer a new, single-item measure of STEM identity, the STEM-PIO-1, that can be easily administered to diverse populations, and which has shown preliminary evidence for its validity and reliability. Future research should continue to test the merit of the measure so as to advance and unite research in this field.

DATA AVAILABILITY

The datasets analyzed for this study can be found in the Open Science Framework: https://osf.io/dgwsj/.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of Alabama A&M University Institutional Review Board, the Auburn University Institutional Review Board, the Tuskegee University Human Participants Committee (IRB), and the Oakland University Institutional Review Board, with electronic informed consent from all subjects. All subjects gave informed consent in accordance with the Declaration of Helsinki. The protocol was approved by the Alabama A&M University Institutional Review Board, The Auburn University Institutional Review Board, the Tuskegee University Human Participants Committee (IRB), and the Oakland University Institutional Review Board.

AUTHOR CONTRIBUTIONS

MM is co-PI on the NSF grant funding the research. MM contributed to the design of all studies, playing the primary role in the design of studies 2 and 3. MM reviewed survey materials prior to distribution for Studies 1 and 2, and generated the survey for Study 3. MM wrote initial drafts of all sections of the manuscript and integrated feedback from co-authors throughout the editing process. MM was responsible for the data analysis and reporting for all studies. MM prepared the manuscript for submission. VZ-H is co-PI on the NSF grant funding the research. VZ-H contributed to the design of the studies and provided input regarding data analysis. VZ-H provided feedback on the manuscript. JV prepared the data files and syntax files for analysis. JV provided feedback on the manuscript throughout the revision process. ME serves as PI on the NSF grant funding the research. ME contributed to the design, selection of instruments, development of the theoretical framework and review of the manuscript, and coordinated data collection at the participating institutions.

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