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Exploring STEM Identity Formation: Survey Research on the Student Experiences in a STEM-Focused Community College and High School Partnership Program

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Abstract

This study investigates the development of student identities within an academic setting that aimed to foster a STEM identity among second-year Associates of Science degree students. Employing a survey research approach, the study analyzed data from a total of 33 participants who completed the survey encompassing 24 math identity and 23 science identity items, rated on a 5-point Likert scale. Findings revealed the perceived lack of recognition of students' math identity from teachers, families, and their social groups, as well as a devalued sense of the value of their culture in supporting their math success. Science identity results showed moderate recognition from peers and teachers and low media representation. Notable gender differences emerged, with males more likely to receive encouragement and feel self-reliant in math, while females were less likely to perceive positive external validation. Additional statistical analyses indicated a moderate to strong association between gender and survey responses. These results highlight the necessity of attending to intersectional identities in constructing educational interventions to ensure inclusive and supportive environments for all students.

Keywords: STEM identity, community college, math and science education, gender disparities, socio-cultural influences

Recommended Citation

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This study is an inquiry into the distinct facets of student mathematics and science identities upon completing a community college program designed to bolster engagement with mathematics and science. Through the pilot project titled the Experiential Learning STEM Opportunity for Latinos (ELSOL), which recruited Associates of Science majors at a Hispanic Serving Institution, we were able to identify areas of need related to identity to inform program improvement. We hope practitioners can draw on the findings and conclusions herein to understand the impacts of similar program participation in communities with large populations of Hispanic students or other students marginalized by race, gender, and socio-economic status.

This project is guided by scholarship about environments that provide opportunities for students to develop, sustain, and actively author their own identities and academic pathways (Rahm & Moore, 2016). We acknowledge the dynamic interplay between internal identity frameworks and external influences, emphasizing the culturally embedded social and educational milieu in which our student participants are situated.

Classroom experiences and the institutions in which they are situated are powerful socializing forces toward identity formation. Indeed, educators have enormous power as agents of the broader educational system and as representatives of society to constrain student agency (Anyon, 1981). In intentionally designed educational environments, they can also promote student agency that invites multiple modes of thinking and acting that can include accountability to their peers and themselves (Anyon, 1981; Cobb et al., 2009; Grant et al., 2015).

Additionally, identifying with an academic domain (such as STEM)—that is, seeing oneself as a certain kind of person and adopting associated ways of thinking and acting—is shaped by various dynamic influences over time, beyond the limited context of classroom experiences. These influences include subjectively interpreted experiences encountered through family dynamics, teacher interactions, the media, informal learning opportunities, and the political climate. These experiences are the available frames for the making and remaking of student identities, with a focus in this paper on how their academic interests develop over time (Black et al., 2009; Moreno & Rutledge, 2015; Rahm & Moore, 2016).

We refer to the sum of these identity aspects as the *identity landscape* in the sense that identity is made by multiple social processes which include material landscapes (including those imposed on individuals such as social status) and which contribute to how people make sense of who they are (Brace, 2003). By engaging with students at a critical point in their academic and professional development, this study offers insights into student identities within a program designed to foster connections and promote tangible actions that support continued participation in STEM fields. Understanding students' perspectives on various aspects of their identity experiences will give us a deeper understanding of the gaps that programs like ELSOL can address. It will also inform practitioners and researchers about the positive factors students rely on to sustain their educational journeys.

Ultimately, we aim to enrich the understanding of identity development within STEM education and contribute to the advancement of inclusive educational practices. This paper focuses on quantitative survey data to comprehensively investigate identity STEM formation.

Literature Review

Mathematics Identity

Mathematics identity researchers have investigated numerous components that constitute mathematics identity as well as elements related to it. One conceptualization of math identity identified two sub-constructs: how others perceive an individual and the level of personal interest in the subject (Cribbs & Utley, 2023). In a previous study, the same authors demonstrated that mathematics identity is a significant predictor of interest in STEM careers (Cribbs et al., 2021). Drawing on Dweck's (2016) concepts of a fixed vs a growth mindset, i.e. whether one believes that intelligence is innate and unchangeable or that it is malleable, they found through their measure of mindset that a malleable view of mathematical intelligence may enhance undergraduate students' identification with mathematics and in turn can increase one's interest in a STEM career. The connection between identity, how students learn, and their career choices is crucial to understand if we want more students to choose STEM (Cribbs et al., 2021.

The elitism surrounding mathematics performance and its use as a tool for social stratification have intensified critiques of traditional, structured, or lecture-driven teaching methods (Boaler, 2002). Mathematics education research and teacher development have extensively focused on understanding the impact of restructuring classroom dynamics to incorporate self-efficacy as an educational goal alongside content knowledge acquisition.

Approaches to achieving these ends are exemplified by methods such as problem-posing, open-ended tasks, and other reform efforts (Rosli et al., 2014). Indeed, inquiry-based, participatory, and authority-sharing are associated with a stronger identification with science and math disciplines (Grant et al., 2015; Hazari et al., 2010; Jiang et al., 2022). School-based environments, including the activities and social structuring within them, are pivotal in developing identification constructs (Cobb et al., 2009; Grant et al., 2015). For example, Grant et al. (2015) focused on the importance of allowing for student collaboration to foster self-reliance. Similarly, the participants in Cobb et al. (2009) began to do mathematics to satisfy their interests rather than as a performance for teacher affirmation.

Science Identity

Work to understand science identity is similar to that on math identity in that there is a relationship between beliefs people hold about themselves, beliefs of others about a person, and how well one can or believes one can participate as a member of the science community (Carlone & Johnson, 2007; Godwin et al, 2013; Hazari et al., 2010). Carlone and Johnson's (2007) framework posited three major contributors, often operationalized as precursors or factors of science identity: science-related social performances, science-related knowledge and competence, and a sense of recognition as a science person. Hazari et al. (2010), who investigated physics identity, developed a related model that combines the attributes of performance and competence into a single category (i.e., performance-competence), measured by individuals' beliefs about their ability to perform and understand physics in school. Godwin et al.'s (2013) science identity model aligns with the structure of the physics identity model in positing a direct path from science interest and science recognition to science identity.

As in the case of mathematics education research, student-centered approaches have been promoted toward more engaged learning and inclusivity (Atwater, 1996). Early efforts to understand the advantages of student-centered, constructivist-based approaches focused on the quality of content delivery, particularly as students participated more actively in various forms of communication (e.g. asking novel questions about the content) (Marbach-Ad & Sokolove, 2002). As these approaches were more and more accepted, research on instructional redesign incorporating active learning and student-centered pedagogy into traditional science courses, revealed improvements in student attitudes and performance (Armbruster et al., 2009). More recent findings suggest that student-centered learning, such as problem-based learning, can effectively support science identity development when emphasis is placed on scientific inquiry, technological application, mathematics processing (Jiang et al., 2022).

Social Factors that Influence Identity

Beyond the classroom, it is important to consider a student's social world and related interactions in shaping their personal and academic identities. Families are the primary socializers of students, and their impact on college-going for their students is important to understand (Kiyama et al., 2016; Kiyama & Harper, 2018). Examples such as Moote et al. (2020) explored the relationships between student science capital, aspirations, and attitudes for each of the four STEM subfields (i.e., science, technology, engineering, and mathematics). Moote et al.'s (2020) "science capital index" (p. 1236) included items that assessed various dimensions of science capitol such as whether parents valued science, whether students talked with others about science, and whether individuals in their families worked in science. A composite science capital score derived from these items showed significant positive correlations with parent attitudes and child aspirations toward STEM. Similarly, Dou and Cian's (2022) results, derived from structural equation modeling, underscored the significant impact of home support and science talk on STEM recognition and in their implications suggested that family engagement be included in programs to foster STEM.

Unfortunately, primary socializers, such as family, friends, and educators, may not have the resources or backgrounds to engage in science-related dialogue with students. In one study by Peralta et al. (2013), students who felt unprepared for school were placed below their grade level and struggled with self-esteem. Parents supported their children by encouraging them and emphasizing the value of education, as they were unable to provide academic help primarily due to linguistic and educational differences. Additionally, the encouragement they provided did not extend to encouragement in science courses.

This last point reminds us of how heavily identities are influenced by our social position, often tied to culture, gender, and race (Peralta et al., 2013). The social positioning associated with race comes through strikingly in Visintainer (2020). The minoritized participants shared their complex educational paths that involve expectations of who can be a scientist (others, white, Asian), how society views them (lacking in intellectual capacity), and the opportunities available to them (socio-economic and political barriers). At the same time, some participants held to the notion that they as individuals have some control over their entry to a powerful social position (see also Moreno & Rutledge, 2019). Unfortunately, many educators may hesitate to engage with issues of race because it is less risky to adhere to a color-blind or culture-free approach to teaching their subject (Shultz et al., 2023). In fact, students of color who often experience discriminatory interactions with faculty members are less likely to be retained in a

STEM degree (Park et al., 2020) and therefore a non-neutral stance on the racial aspects of STEM identity building, such as educator-facilitated identity development, building multiple pathways to STEM, and increasing faculty diversity (Flowers & Banda, 2016) is worthy of consideration.

Aside from race, we consider gender bias which works to assign socially accepted roles to women (Damarin, 2000; Wang & Degol, 2017). This role may clash with the perceived role of being a scientist and women who have internalized these biases who often need affirmation such as through role models to help them understand they belong (Packard & Wong, 1997). Similarly, Hazari et al. (2010) found that females were significantly less likely to report that their high school physics classes focused on conceptual understanding, included labs addressing their beliefs about the world, discussing currently relevant science topics, or discussing the benefits of being a physicist—factors that are positive predictors of physics identity. Even when controlling for home support and parental education, participants identifying as female tended to report a lower sense of performance competence, reaffirming findings from prior work that identified systemic challenges facing women pursuing STEM fields (Dou & Cian, 2021). Notably, a significant gender interaction from one quantitative model illustrated that explicit discussion of the underrepresentation of women in science has a positive impact on physics identity for female students (Hazari et al., 2010).

Intersectionality and STEM Identity

Understanding how gendered and racial/ethnic identifications intersect in STEM learning spaces is crucial. One study that examined the relationship between demographic category, math identity, and student perceptions of teachers' equity practices, found that Latinx girls had significantly lower math identities compared to both white girls and Latinx boys, highlighting a gender disparity within the Latinx student population (Shifrer et al., 2023). This suggests that Latinx girls face more challenges in developing a positive math identity. Additionally, Latinx girls were significantly more likely to perceive their math teachers as inequitable relative to both white girls and Latinx boys, indicating that they might experience or perceive more bias or unfair treatment from their math teachers (Shifrer et al., 2023). Another study that focused on predominantly Hispanic females, compared the effects of stereotype threat in different environments—a standard math classroom versus an honors math classroom (Casad et al., 2017). The results were context-dependent. Notably, under stereotype threat, girls in standard math classes reported more negative attitudes and greater disengagement from the math domain, with gender identity being a risk factor. Conversely, in the identity safety condition, gender identity acted as a protective factor (Casad et al., 2017).

Conceptual Framework for This Study

This study is a look into the nature of the development of students' identities as they engage in an academic setting structured to support a general STEM identity. Math and science identity have been conceptualized as distinct ways of viewing oneself and also how they relate to concepts such as career choice. However, it is important to also describe a perspective that is key to the project undertaken, which is how beliefs develop in relation to our experiences. These include direct experiences, such as engaging in scientific activities, but also socio-cultural experiences, such as being schooled in inequitable environments. Our conceptual lens for this study is largely influenced by Black et al. (2009) analysis of the interplay between one's developing internal structuring around a particular identity and the environment which through actions within it continually redefines/refine that internal construct. Regarding identity, Black et al. said:

> The self is always mediated through the student's leading activity—i.e. through actions which result in an outcome which is more significant than the original motive which induced it. This defines 'change' as an ongoing, socially situated process whereby the internal mind and social world are always in dialectic relation. (p. 70)

We also drew on our work with adult students in community college mathematics environments (Moreno & Rutledge, 2019) that supports the notion of the continual remaking of identity when supportive environments allow participants to be active agents in their education. In particular, the ELSOL program was designed to create opportunities that allowed participants to imagine novel outcomes for themselves.

Research Questions

Despite existing research, there remains a gap in understanding the comprehensive nature of student identity development within structured academic environments emphasizing mathematics and science. This study aimed to address this gap by employing survey methodologies to explore the interplay between internal identity structures and external environments. Key research questions included how students perceive and engage with mathematics and science, the influence of social factors on identity formation, and the implications for fostering inclusive STEM education environments. Our research questions were as follows:

1. Which aspects of the math and science identity landscape are challenging for students based on their relative survey responses, even after completing the ELSOL program?
2. Is there a relationship between gender and any of the aspects of the math and science identity landscape?
3. Is there a relationship between gender and students' overall math and science identity based on the math and science identity landscape framework?

Through rigorous data collection and analysis, this research aims to provide a nuanced understanding of student identity development across STEM disciplines.

Methodology

The larger study employed a convergent mixed-methods research design, incorporating both quantitative and qualitative data collection methods. Convergent mixed-methods designs deploy both data collection tools (quantitative and qualitative) at the same time and later work to integrate the results (Fetters et al., 2013; Merriam & Tisdell, 2014). For this article, we present the survey research component of the larger project. This survey gathered descriptive data on student demographics and their perceptions of their math and science identity. Participants provided information about their age, gender, and educational background. Additionally, the survey included items specifically designed to assess the development of math and science identities among the student cohort. By systematically collecting and analyzing this quantitative data, the study sought to provide insights into the program's impact on student identity formation in the mathematics and science disciplines. The qualitative research, which utilized focus groups and interviews to collect data, provided contextual information and more direct data about program facets that influenced student experience and thus informed identity formation.

Population and Sampling Techniques

The setting of the study encompassed two distinct educational institutions in the Southwest United States: Southwest Community College (SCC) and South County Early College High School (SCECHS) (both pseudonyms). SCC, a branch of the local university, offers a range of programs designed to facilitate students' transfer to 4-year institutions, providing a diverse and dynamic community college environment. Conversely, SCECHS is located in a rural area of the county in which both institutions are located. The SCECHS caters to high school students by offering dual credit and degree opportunities through SCC to help students accelerate their academic progress. This setting allowed the study to capture a broad spectrum of pre-transfer students from both urban and rural backgrounds, further contributing to the diversity and richness of the data collected. The rural context of SCECHS provided unique insights into the challenges and opportunities faced by students in less urbanized areas, while SCC's connection to the local university highlighted pathways to higher education and the transition dynamics between 2-year and 4-year institutions.

The sampling method used in this pilot study involved a combination of purposive and convenience sampling (Merriam & Tisdell, 2014). Purposive sampling operates on the idea that researchers aim to gain insight and understanding by selecting participants who offer the most potential for learning, making it a suitable approach for the qualitative aspect of this mixed-methods study (Merriam & Tisdell, 2014). Convenience sampling is the use of subjects which are conveniently available to the researcher; we believe that aside from the opportunity to guide the refinement of the instruments, there are some promising results that can be pursued in the future (Patten, 2011).

Participants were pre-transfer students in their final year at either SCC or SCECHS. The inclusion criteria initially focused on second-year students pursuing an Associate of Science degree at either institution. Recruitment strategies involved close collaboration with community college advisors and school personnel, particularly the SCECHS Principal and Guidance Counselor, who played a pivotal role in identifying and engaging eligible students. In the first year, 16 students were recruited, representing 67% of the targeted enrollment, with the majority hailing from SCECHS. This indicated a need to enhance recruitment efforts from SCC in subsequent years. The inclusion criteria were adjusted in the second year to allow for broader student enrollment, ultimately resulting in a total of 17 participants, again predominantly from ECHS. The combined total was 33 students who completed the post-program survey. This approach ensured that the sample was representative of the target population, while also addressing practical constraints and recruitment challenges.

Development and Validation of Survey Instrument

In this study, a survey instrument was developed to assess math and science identity among undergraduate students, drawing upon the existing literature on math and science identity cited above. Although some research hypothesizes a stable STEM identity (Dou & Cian, 2022), we addressed mathematics and science identity separately for several reasons.

First, the field of mathematics education has significantly influenced K-12 pedagogy over the past 30 years, primarily through constructivist and social constructivist philosophies (e.g., Schoenfeld, 1983; Yackel & Cobb, 1996). This influence has shaped curriculum and valued methodologies, particularly in primary and secondary mathematics classrooms. Additionally, the intersection of habits of mind associated with mathematics (e.g., algebra, pattern recognition, multiple representations) (Cuoco et al., 1996) and the critique that Western mathematics is used to exclude certain populations (Bishop, 1990; D'ambrosio, 1985) warrants it distinct consideration.

While science education has also been influenced by constructivist-centered methodologies, including those that call for the need of diverse ways of interpreting the natural world (Atwater, 1996; O'loughlin, 1992; Rodriguez, 1998), it has been importantly shaped by Kuhn's (1997) thesis on paradigmatic shifts and the potential emphasis on historically and culturally embedded process of change. Moreover, the empirical approaches used in biology, chemistry, and physics differ from those in mathematics.

The Math Identity Survey consists of 24 items, and the Science Identity Survey consists of 23 items that were developed to capture various dimensions of math and science identity, including self-perceptions, attitudes, beliefs, and behaviors related to mathematics and science. The survey was measured using a 5pt. Likert Scale where 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, and 5=Strongly Agree. The development process involved several key steps to ensure the instrument's construct validity and reliability, including item generation and expert review. The initial pool of survey items was generated based on a comprehensive review of the literature on math and science identity (Carlone, et al., 2007; Cobb et al., 2009; Flowers & Banda, 2016; Tate & Linn, 2005). Items were designed to capture various dimensions of math and science identity, including self-perceptions, attitudes, beliefs, and behaviors related to mathematics and science. Content area experts in math and science education and survey methodology were invited to review the survey items, providing feedback on clarity, relevance, and comprehensiveness, as well as suggestions for revisions and additions. Based on expert feedback, modifications were made to refine and improve the survey items to enhance their validity. The final version of the survey instrument comprised a set of validated items designed to comprehensively and accurately assess math and science identity among undergraduate students. Using the final data set for the post-intervention survey (combined MIS and SIS), a split-half reliability Spearman-Brown coefficient of 0.92 resulted.

For construct validity, Hazari's (2010) model, which posits that identity is comprised of recognition by others and individual interest in a domain, was followed. A combined score was created using the following questions: "Other people think I am good at math," "I find mathematics activities meaningful," "My peers and/or my teachers see me as a science person," and "I see myself using scientific principles in my future job." This yielded a Recognition and Interest Score. A total STEM identity score was created by averaging all math identity questions and all science identity questions, then combining these averages to create a Total STEM Identity Score. The Pearson correlation between these scores was 0.79, indicating a strong positive correlation between the Recognition and Interest Score and the Total STEM Identity Score.

Data Collection Procedures

The data collection methods and procedures for this pilot study included a survey instrument and focus groups to assess math and science identity among undergraduate students. Two primary initiatives were employed to cultivate mathematical and scientific identities: professional development for mathematics faculty and experiential learning for students.

The first initiative focused on improving instructional methods through the Micro Messaging Academy, facilitated by a national STEM and career and technical education equity focused organization. This academy provided training on cultural stereotypes, implicit bias, micro messaging, neuroscience, and social learning theories. Faculty members then implemented action research projects to modify teaching practices, aiming to enhance student self-efficacy, foster growth mindsets, and prioritize student-centered approaches.

The second initiative involved engagement through experiential learning, where students participated in undergraduate research and mentoring experiences. This was primarily executed through two one-credit interdisciplinary Science, Technology, Engineering, and Mathematics (STEM) courses, STEM 101 and STEM 102, taken by program students in the Spring of 2022 and throughout the 2023 academic year. These courses utilized a Citizen Science approach, allowing students to engage in real scientific research under professional supervision. Activities included observations with NASA’s Radio Jove radio telescope, data analysis, and introductory classes in astrobiology and engineering, with a focus on data science using Python, a versatile, high-level programming language designed for coding.

Students' engagement and learning outcomes were further documented through presentations at an undergraduate research and arts symposium hosted by the local university and at an international conference on astronomy education, showcasing their accomplishments and fostering a higher level of engagement and interest in STEM fields. The STEM courses’ instructor observed that students demonstrated increased enthusiasm when involved in hands-on coding and data analysis activities, suggesting the effectiveness of experiential learning over traditional instruction. This comprehensive approach to data collection aimed to provide a robust understanding of the impact of the program on student identity formation in math and science disciplines.

Ethical Considerations and Approval

Ethical considerations and approvals for this study were obtained through the Institutional Review Board (IRB) at the local university, where the principal investigator (PI) and his team are affiliated. The IRB approval process ensured that the study adhered to ethical guidelines and standards for conducting research involving human participants. Specifically, the IRB reviewed and approved the study protocol, including the methods for recruitment, data collection, participant consent procedures, and the inclusion of students from SWECHS. Given the study's focus on enhancing educational outcomes and student engagement in STEM fields at SCC and SCECHS[1], special attention was paid to protecting participant confidentiality and ensuring voluntary participation. IRB approval provided assurance that the research procedures

[1] The Director of Secondary Education at SECHS reviewed the grant proposal, which included the research methods, prior to submission and provided a Letter of Support.

were conducted ethically and in accordance with institutional and federal regulations, thereby safeguarding the rights and welfare of all participants involved in the study.

Results

Julius AI was employed to conduct statistical analyses of the survey data. Given the small sample size, effect size analysis was be employed to assess the magnitude of outcomes specific to participants in this group. This approach allows for a focused examination of the results pertinent to our study cohort, ensuring a nuanced understanding of the impact of interventions or treatments implemented. Table 1 presents the demographic, academic, and financial characteristics of students in the ELSOL Program.

Among the 22 students surveyed in the ELSOL Program, the majority are pursuing an Associates of Science or Associates of Science Pathway (77.3%). Smaller groups are focused on General Engineering (13.6%), Electronics Technology (4.5%), and other STEM fields (4.5%). If transferring to a 4-year institution, most plan to major in Engineering (59.1%), with others choosing Agricultural, Animal or Food Science (13.6%), Biology (9.1%), other STEM degrees (9.1%), Exercise Science (4.5%), and Chemistry (4.5%).

Regarding math courses, the most common classes taken are Calculus I (40.9%), followed by Pre-Calculus and Trigonometry (22.7%), and Statistics (13.6%). Few students took Calculus II (4.5%) or other unspecified classes (9.1%), and some did not take any math class (9.1%).

Financially, 57.8% of students qualify for Pell Grants and 62.2% for free or reduced lunch. Gender distribution is predominantly female (57.8%), with males making up 35.6%, and 4.4% choosing not to disclose their gender. The age range shows a majority of 18 – 24 years old students (72.7%), with 13.6% under 18 and 9.1% aged 25 – 34.

In terms of ethnicity, 88.9% of students are Hispanic. Racially, 72.7% are White, 18.2% identify as Other, and 4.5% as American-Indian or Native American or First Nations[2]. Most students are enrolled in university (36.4%), with equal proportions in community college and high school/early college/dual credit programs (31.8% each). Below is a demographic table with the counts and percentages for each category.

[2] Both ethnicity and race indicators are given as primary indicators of the complex nature of ethnic and racial identification. A discussion about this identification to include potential impacts on STEM career aspirations is beyond the scope of this article. However, it is important to note that the Hispanic population in the southwest U.S. is not monolithic and includes individuals who identify with their immigrant country of origin (usually Mexico), their colonial Spanish roots, and the Spanish language to varying degrees (Healy et al., 2018; Holleran, 2003).

Table 1

Descriptive Statistics of ELSOL Program Students

Category	Sub-category	Count	Percentage (%)
Current Majors	Associates of Science/Science Pathway	17	77.3
	General Engineering	3	13.6
	Electronics Technology	1	4.5
	Other STEM fields	1	4.5
Intended 4-year Majors	Engineering	13	59.1
	Agricultural, Animal or Food Science	3	13.6
	Biology	2	9.1
	Other STEM degrees	2	9.1
	Exercise Science	1	4.5
	Chemistry	1	4.5
Math Classes Taken	Calculus I	9	40.9
	Pre-Calculus and Trigonometry	5	22.7
	Statistics	3	13.6
	Calculus II	1	4.5
	Other classes	2	9.1
	Not taking a math class	2	9.1
Financial Aid	Qualify for Pell Grants	13	57.8
	Qualify for free or reduced lunch	14	62.2
Gender Distribution	Female	13	57.8
	Male	8	35.6
	Did not wish to answer	1	4.4
Age Range	Under 18	3	13.6
	18-24 years old	16	72.7
	25-34 years old	2	9.1
Ethnicity	Hispanic	20	88.9
Race	White	16	72.7
	Other	4	18.2
	American-Indian/Native American/First	1	4.5
Current Enrollment	University	8	36.4
	Community College	7	31.8
	High School/Early College High	7	31.8

Note. This table presents the demographic, academic, and financial characteristics of students in the ELSOL Program. Percentages are calculated based on the total number of respondents (N = 22).

Math and Science Identity Survey

For the Math and Science Identity Surveys, the authors present data on the high, middle, and low scoring items. Table 2 shows the results of the Math Identity Survey (MIS). The results indicate that at the low end, and in comparison to the middle and high scoring items, students generally believe in the success potential of individuals with similar backgrounds in mathematics (Mean = 4.10), that they take control of their own learning (Mean = 4.10), and that their allowed to develop their own solutions (Mean = 4.10). They also responded that they have chosen math-related majors to make a positive impact (Mean = 4.00). However, there are significant concerns. Notably, students feel only moderately that they bring important cultural values into the math classroom (Mean = 3.85) and that others perceive them as good at mathematics (Mean = 3.76). The perceived encouragement from family and friends (Mean = 3.68) and particularly from teachers (Mean = 3.57) are notably lower.

Table 2

Mathematics Identity Survey Questions and Means

Question	Mean
High Scoring Questions	
Learning math will help lead me to the career I want.	4.52
I can overcome any barriers to succeeding in my math class in order to achieve my career goals.	4.52
I am hardworking enough to succeed in a math coursework.	4.52
I believe that learning mathematics is an important part of my career pathway.	4.45
I collaborate with my classmates to solve mathematical problems.	4.43
I can become better at mathematics if I work hard.	4.38
I see myself using mathematics in my future job.	4.38
I see myself as capable of using my mathematical knowledge to understand newsworthy or other important issues.	4.33
Middle Scoring Questions	
I find mathematics activities to be engaging.	4.33
I find mathematics activities to be meaningful.	4.29
I am self-reliant when studying math (finding resources, managing time, asking questions when I need help).	4.29
I know I will understand concepts eventually as long as I am persistent.	4.24
I am intelligent enough to do well in math courses.	4.24

(continued)

I don't mind working on challenging mathematics problems.	4.24
I know that mathematics was developed by different cultures from around the world including my own.	4.23
I enjoy solving equations and/or solving problems.	4.14
Low Scoring Questions	
I take control of my own learning in math class.	4.1
I am allowed to develop my own solutions to problems in mathematics.	4.1
I know that people that have similar backgrounds to me can succeed in math.	4.1
I have chosen a major that involves mathematics in order to make a difference in the world.	4.0
I bring important cultural values into the math classroom that help me succeed.	3.85
Other people think I am good at mathematics.	3.76
My family and/or friends think I should do something that involves mathematics.	3.68
My teachers have encouraged me to choose a career that involves mathematics.	3.57

Note: Questions were rated on a 5-point scale. *N*=22.

These findings suggest a need for increased support and recognition from both family and educational environments to strengthen students' math identity and confidence. Teachers' encouragement, in particular, appears to be a critical area for intervention to help students feel more supported in pursuing math-related careers.

Table 3 shows the results of the Science Identity Survey, again with the high, middle, and low scoring items grouped. At the low end, students generally believe they understand the stages of scientific experiments (Mean = 4.14), possess practical science (Mean = 4.14), and that they have an interest in scientific topics and fields (Mean = 4.14). The results indicate that students generally engage in science activities that interest them (Mean = 4.10) and align their career goals with science disciplines (Mean = 4.10). However, there are notable concerns regarding the lower scores. Collaboration with classmates on scientific questions (Mean = 4.05) and recognition as a science person by peers and teachers (Mean = 3.86) are somewhat moderate. The portrayal of people from similar backgrounds as scientists in the media (Mean = 3.81) and discussions about science with family or close adults (Mean = 3.48) received even lower ratings. (As above, these are the 8 among 23 questions yielding the lowest means).

Table 3:

Science Identity Survey Questions and Means

Question	Mean
High Scoring Questions	
My instructors treat me and others from similar backgrounds in a fair manner.	4.43
I am hardworking enough to succeed in a science program.	4.38
I am self-reliant when studying science (finding resources, managing time, asking questions when I need help).	4.29
I know which career/s I can pursue if I major in a scientific discipline.	4.27
I have chosen a major that involves science in order to make a difference in the world.	4.24
Engaging in science activities helps me see myself as a scientist.	4.24
I am curious about things that can be explored through science or through the scientific process.	4.24
Middle Scoring Questions	
I am intelligent enough to do well in science.	4.24
I see myself using scientific principles in my future job.	4.24
I am able to comprehend scientific principles.	4.19
My family sees me as someone who can succeed in science.	4.19
I have access to career resources (mentors, career services, guidance counselors).	4.19
People from ethnic or racial backgrounds similar to mine can succeed in science.	4.19
I see myself as capable of using my scientific knowledge to understand newsworthy or other important issues.	4.15
Low Scoring Questions	
I know how to conduct a scientific experiment/I can identify the stages of a scientific experiment.	4.14
I have practical science skills (lab skills, writing hypothesis, analyzing data and results, drawing conclusions).	4.14

(continued)

I am interested in topics in general science or in a specific scientific field (biology or microbiology, chemistry, physics, physical science, astronomy, engineering, environmental, etc.)	4.14
The science activities I engage in are based on problems I am interested in.	4.1
My career goals are aligned with a major in a science discipline.	4.1
I collaborate with my classmates to address scientific questions.	4.05
My peers and/or my teachers see me as a science person.	3.86
People from backgrounds similar to mine are portrayed as as scientists in the media.	3.81
I discuss science with my family, a parent, or another close adult.	3.48

Note: Questions were rated on a 5-point scale (*N*=22).

These findings suggest a need for enhancing collaborative opportunities and stronger recognition of science identity by peers and teachers. Additionally, improving the representation of diverse backgrounds in scientific roles in media and fostering more discussions about science within families and close social circles could support and strengthen students' science identity.

Gender Differences in Math and Science Identity

To better understand the role of gender, given that institutional data indicates a significant difference in enrollment of females in Associates of Science and Associates of Science-General Engineering as compared with males (χ^2, p <. 01), the authors conducted a comprehensive statistical analysis with gender as the independent variable. This analysis aimed to delve deeper into the findings from the identity surveys and to explore the influence of gender on students' perceptions
and attitudes towards STEM fields. Previous literature has extensively examined identity in STEM fields, particularly focusing on marginalized populations and the intersectionality of race, gender, and culture (Amon, 2017; Carlone & Johnson, 2007; Casad et al., 2017; Packard & Wong, 1997; Rodriguez & Blaney, 2021; Tate & Linn, 2005).

Given that our study is situated in a southwest border region, where the majority of students identify as Hispanic and first-generation, it was imperative to explore the specific gender dynamics within this unique demographic context. The majority of participants in this study were Hispanic 88.9%, which allows us to isolate and examine the influence of gender on STEM identity without the confounding variable of race. In this region, cultural factors play a significant role in shaping educational pathways and career aspirations. Despite the fact that 60.3% of students at this institution are female, a disproportionately low percentage (52%) of the female students have declared an Associates of Science or Associates of Science-General Engineering major. This gender disparity in STEM representation stresses the need for a focused investigation into the barriers and facilitators of math and science identity development among female students in this cultural context.

In examining the role of gender in the development of math and science identity among students, the authors used the Fischer's Exact Test to assess the associations and differences in survey responses. The Fisher's Exact Test was chosen for its ability to handle small sample sizes and provide exact p-values, offering a precise method to determine if the observed associations are statistically significant. This test is particularly appropriate given the sample size (N = 22) in our study. Effect size, measured with Cramer's V, is particularly useful in this study because it allows for the measurement of the strength of association between gender and survey responses, ranging from 0 (no association) to 1 (perfect association). The odds-ratio is a measure of association between two binary variables. It quantifies how much more likely an outcome is to occur in one group compared to another group. These measures are important is in understanding how strongly gender influences perceptions and attitudes towards math and science identity. Table 4 shows the results of the Fisher's Exact test results with Gender and the Odds Ratio and Cramer's V for those with P-values less than 0.05. Results indicate female ratios are low compared to males in above the mean vs. below the mean measures.

Table 4

MIS & SIS Fisher's Exact Test Results with Gender and Odds Ration and Cramer's V

Question	Odds Ratio	Cramer's V	Mean	P-Value
My family and/or friends think I should do something that involves mathematics.	0.06	0.20	3.68	*0.024
My teachers have encouraged me to choose a career that involves mathematics.	0.06	0.20	3.57	*0.024
I believe that learning mathematics is an important part of my career pathway.	0.00	0.22	4.45	*0.007
Learning math will help lead me to the career I want.	0.00	0.22	4.52	*0.018
I can overcome any barriers to succeeding in my math class in order to achieve my career goals.	0.00	0.22	4.52	*0.018
I see myself as capable of using my mathematical knowledge to understand newsworthy or other important issues.	0.06	0.20	4.33	*0.024
I am self-reliant when studying math (finding resources, managing time, asking questions when I need help).	0.06	0.20	4.29	*0.018
I don't mind working on challenging mathematics problems.	0.06	0.20	4.24	*0.024

Note. Fisher's Exact test results with Gender and all survey questions. This also shows the odds ratio, and Cramer's V for those with P-values less than 0.05. *N*=22 (Female: *N*=13, Male: *N*=8, Did not wish to disclose: *N*=1).

This test only found significant differences with gender as the independent variable on the MIS; no significance was found on any items from the SIS at the .05 significance level. The results from the Math Identity Survey indicate that gender plays a notable role in the responses to several questions related to mathematics. Specifically, the odds ratios for questions such as "My family and/or friends think I should do something that involves mathematics," "My teachers have encouraged me to choose a career that involves mathematics," "I see myself as capable of using my mathematical knowledge to understand newsworthy or other important issues," "I am self-reliant when studying math (finding resources, managing time, asking questions when I need help)," and "I don't mind working on challenging mathematics problems" are all significantly greater than 1. This suggests that males are more likely than females to agree with these statements.

The odds ratios for the questions indicate that the likelihood of positive responses (e.g., agreement with statements about mathematics) is generally lower for one gender compared to the other, as evidenced by values significantly less than 1. For instance, the odds ratio of 0.089 for the question "Other people think I am good at mathematics" suggests that one gender is much less likely to perceive positive external validation in mathematics compared to the other. Cramer's V values, ranging from approximately 0.38 to 0.51, indicate a moderate to strong association between gender and responses to these questions, suggesting that gender plays a significant role in shaping perceptions and attitudes towards mathematics. These findings highlight the importance of considering gender differences in educational interventions and support systems to foster a more inclusive and encouraging environments for all students.

Discussion

The results from the MIS and the SIS reveal that the social aspects of educational pathways are fragile components of student identities, posing significant hazards to their development. Teachers are notably absent in providing recognition and encouragement for both the mathematical and scientific aspects of students' identities. Similarly, families struggle to offer support, either through encouragement or by engaging with students' interests. Peers also fail to affirm students' alignment with their chosen educational or career pathways, and there is a lack of social opportunities, such as collaboration, to help construct a stronger social identity. Furthermore, if cultural values are transmitted through our social groups, a diminished sense of their importance to success can lead to a perception of misalignment with one's community, further weakening the sense of recognition and support. This affirms what students have noted elsewhere—that for minoritized students, "their academic selves [are] not fully integrated with their lives outside the classroom" (Moreno, 2015). That said, we note that students in these programs come with clear career aspirations, self-efficacy and work ethic, and curiosity about their worlds; specific questions related to these ranked high in comparison to other questions in both the MIS and the SIS.

To further analyze the gender disparities in mathematics identity, Fisher's Exact Test was administered with all survey questions (MIS and SIS). The results revealed a strong association between gender and these perceptions, indicating that gender significantly shapes students' beliefs and attitudes towards mathematics. This discussion integrates these findings with relevant literature to provide a nuanced understanding of how gender influences the development of mathematics identity, particularly within the context of a predominantly Hispanic student population in a southwest border region.

Perceived Encouragement and Support

Understanding the gender disparities in STEM education is crucial for fostering equitable learning environments. The results of the MIS show that males consistently reported higher levels of perceived encouragement from both family and teachers regarding careers involving mathematics compared to females (Casad & Bryant, 2017; Hazari et al., 2010). This disparity underscores the critical role of supportive environments in shaping students' aspirations and confidence in STEM fields, particularly for underrepresented groups like females. Previous studies have found that encouragement from teachers and family members significantly impacts students' self-efficacy and career aspirations in STEM fields (Godwin et al., 2013). Females, often subject to stereotype threat and societal biases, may benefit disproportionately from supportive networks that validate their potential in mathematics (Casad & Bryant, 2017).

Self-Reliance and Mathematical Confidence

Additionally, results of the MIS revealed that male students demonstrated greater self-reliance and confidence when studying mathematics, indicating a stronger belief in their ability to manage challenges independently. This finding aligns with Bandura's theory of self-efficacy, which posits that individuals' beliefs in their capabilities influence their academic performance and career choices (Bandura & Wessels, 1997). Research suggests that females may face greater challenges in developing mathematical confidence due to perceived gender norms and societal expectations (Boaler, 2002; Damarin et al., 2000; Packard et al., 1997). Consequently, strategies that foster collaborative learning environments and promote self-efficacy among all students are crucial in mitigating these disparities (Anyon, 2005).

Cultural Context and Educational Pathways

Situating this study in a southwest border region with a predominantly Hispanic and first-generation student population offers insights into how cultural factors intersect with gender dynamics in STEM identity development (Peralta et al., 2013; Rahm & Moore, 2016). Cultural values and familial expectations play a significant role in shaping students' perceptions of their capabilities and career aspirations. Studies have shown that cultural values can either support or hinder students' engagement and success in STEM fields, depending on how they align with educational norms and societal expectations (Peralta et al., 2013; Rahm & Moore, 2016). Despite the cultural emphasis on education, particularly in valuing STEM careers, the disparity in STEM major declarations among females is a persistent barrier that may deter female students from fully engaging in STEM fields.

Intersectionality of Gender and Race in STEM Identity

The intersectional analysis of gender and race/ethnicity within STEM identity development underscores the complex interplay of social identities in shaping educational outcomes. Studies about cultural contexts and societal perceptions influence students' STEM identities emphasize the need for tailored interventions that address the unique challenges faced by underrepresented groups, including Hispanic females in STEM fields (Peralta et al., 2013; Shifrer et al., 2023).

The observed gender disparities in mathematics identity align with existing literature that looked into the differential experiences and perceptions of encouragement and support between males and females in STEM fields (Casad & Bryant, 2017; Hazari et al., 2010). Although the SIS did not yield significance, other studies (Dou & Chan, 2022; Hazari, 2010) show that these observed gender disparities also exist in the context of science identity. For the MIS, higher odds ratios for statements such as "My family and/or friends think I should do something that involves mathematics" and "My teachers have encouraged me to choose a career that involves mathematics" suggest that males are more likely to receive positive reinforcement and encouragement from both familial and educational environments. This finding is consistent with studies indicating that males often perceive greater support and validation for pursuing careers in mathematics and related fields, which can significantly influence their confidence and aspirations (Hazari et al., 2010). The findings highlight the importance of targeted interventions, methodological rigor in research, and culturally responsive educational practices to promote equitable opportunities in STEM fields.

Implications for Practice

This study investigates the challenges faced by students marginalized by race, gender, and culture in the context of completing a program designed to foster their STEM identities, which we posit comprise two sub-identities: math and science identities, each composed of multiple elements. The identified disparities are critical areas for educational intervention.

Educational interventions should focus on enhancing teacher encouragement and family support for female students in mathematics to mitigate gender disparities in mathematical confidence and career aspirations (Hazari et al., 2010; Shifrer et al., 2023). Interventions should prioritize fostering encouragement and support systems for female students in mathematics, building on findings that emphasize the positive impact of teacher encouragement and familial support (Hazari et al., 2010; Shifrer et al., 2023) . Effective strategies could include mentorship programs, inclusive classroom practices, and culturally responsive teaching that acknowledges and values diverse perspectives and identities. Incorporating student-centered activities and problem-solving approaches in mathematics education can enhance students' sense of agency and engagement, addressing critiques of traditional lecture-driven methods that may perpetuate gender disparities (Anyon, 2005; Boaler, 2002). These approaches can cultivate a collaborative learning environment where students feel empowered to explore mathematics and develop confidence in their abilities.

Culturally responsive teaching practices should focus on representation and valuing diverse perspectives and identities to create inclusive learning environments that nurture mathematics identity among all students, particularly in culturally diverse regions (Peralta &

Steele, 2013; Rahm & Moore, 2016). Recognizing students' cultural contexts, particularly in diverse regions like southwest border areas, is crucial for designing inclusive educational practices (Rahm & Moore, 2016). Educational stakeholders should collaborate with communities to understand and respect cultural values, thereby creating supportive learning environments that validate students' identities and aspirations.

Program designers and managers should be aware of the intersectional landscape that shapes the identities of individuals they serve, which may be unique to the cultures, languages, and regions in which these programs are implemented; a deeper engagement with participants and their lives outside of school would provide a nuanced view of where students are so as to provide more targeted support (Civil, 2014). Administrators, institutional policymakers, and program directors need to engage with their communities, particularly reaching out to the private sector and influential community organization leaders, to forge partnerships that maintain focus on how students view themselves in relation to those organizations; proper mentoring, re-envisioning evaluation protocols, and promoting collaboration and collegiality are some ways that organizations can establish the opportunity for better outcomes (Amon, 2017; Rodriguez & Blaney, 2021). This is a call to actively work towards dismantling real or perceived barriers to entry into STEM professions, especially since these fields offer pathways to social mobility and economic stability for individuals and their communities.

Finally, practitioner educational researchers should find value in creating interventions aimed at improving student outcomes and identifying opportunities for program enhancement through research. This study underscores the importance of ongoing efforts to promote equitable and inclusive STEM education, fostering environments where all students can thrive.

Limitations and Future Directions

Despite the valuable insights provided by this study, there were several limitations that should be acknowledged. First, the study's sample size was relatively small, with only 22 participants, primarily from South County Early College High School (ECHS). This limited sample size reduces the generalizability of the findings to a broader population. Additionally, the over-representation of ECHS students compared to Southwest Community College (SCC) students may skew the results, not fully capturing the experiences of the latter group. Second, while the study explored the influence of social factors on identity formation, it may not have fully accounted for the broader range of external factors, such as socioeconomic status, parental education levels, and extracurricular activities, which can significantly impact STEM identity development. Finally, the study's reliance on self-reported data could introduce various biases, such as recall bias or social desirability bias, where participants might overstate positive attributes or underreport negative ones. By recognizing these limitations, future research can be designed to address these gaps, thereby enhancing the robustness and applicability of findings related to STEM identity development in diverse educational contexts.

Future research should delve deeper into the intersectionality of race, gender, and socioeconomic status in STEM identity formation. This would provide a more detailed understanding of how overlapping identities influence students’ experiences and outcomes in STEM fields. Evaluating the effectiveness of specific educational interventions designed to enhance STEM identity among underrepresented groups may provide evidence-based strategies for educators and policymakers. Future research should also include exploring additional variables such as socioeconomic status, parental education levels, and extracurricular activities to help identify other critical factors influencing STEM identity development. Implementing longitudinal studies could also provide deeper insights into how math and science identities evolve over time and under varying educational conditions. Tracking students from early academic stages through higher education and into their careers could offer a more detailed understanding of the long-term impacts of educational interventions.

Conclusion

This study emphasizes the pressing need to address gender and cultural disparities in STEM identity development through targeted educational interventions and support systems. Educators, policymakers, and community stakeholders must prioritize teacher encouragement, family support, and culturally responsive teaching to create inclusive and empowering learning environments. These areas appear to be aspects of the identity landscape that need attention if students are to utilize them as resources to build STEM identity. By fostering a sense of belonging and confidence in all students, particularly those from marginalized backgrounds, we hope we can promote greater diversity and equity in STEM fields. This study calls for continued research and collaborative efforts to dismantle barriers and ensure that every student can succeed in STEM fields.

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Appendix A
Demographic Survey

Demographic Section
What is your current enrollment? High School, Community College or Other. /In which institution are you currently enrolled?
Do you or have you ever qualified for a Pell Grant?
Do you or have you ever qualified for free or reduced lunch?
What is your gender or sex identity?
What is your age?
What is your ethnicity?
What is your race?
What was your major during the time you were in the ELSOL Program?/What is your current major?
Are you a first-generation college student? (first-generation college student means that your parents did not complete a 4-year college or university degree.)
What will be your major if you transfer to a 4-year institution?

Appendix B
Mathematics Identity Survey Questions

Other people think I am good at mathematics.
My family and/or friends think I should do something that involves mathematics.
My teachers have encouraged me to choose a career that involves mathematics.
I know that people that have similar backgrounds to me can succeed in math.
I bring important cultural values into the math classroom that help me succeed.
I know that mathematics was developed by different cultures from around the world including my own.
I believe that learning mathematics is an important part of my career pathway.
Learning math will help lead me to the career I want.
I can overcome any barriers to succeeding in my math class in order to achieve my career goals.
I see myself using mathematics in my future job.
I see myself as capable of using my mathematical knowledge to understand newsworthy or other important issues.
I have chosen a major that involves mathematics in order to make a difference in the world.
I take control of my own learning in math class.
I am allowed to develop my own solutions to problems in mathematics.
I collaborate with my classmates to solve mathematical problems.
I am hardworking enough to succeed in a math coursework.
I am intelligent enough to do well in math courses.
I am self-reliant when studying math (finding resources, managing time, asking questions when I need help).
I find mathematics activities to be meaningful.
I find mathematics activities to be engaging.
I enjoy solving equations and/or solving problems.
I can become better at mathematics if I work hard.
I don't mind working on challenging mathematics problems.
I know I will understand concepts eventually as long as I am persistent.

Appendix C
Science Identity Survey Questions

My family sees me as someone who can succeed in science.
My peers and/or my teachers see me as a science person.
I discuss science with my family, a parent, or another close adult.
People from ethnic or racial backgrounds similar to mine can succeed in science.
My instructors treat me and others from similar backgrounds in a fair manner.
People from backgrounds similar to mine are portrayed as scientists in the media.
I know which career/s I can pursue if I major in a scientific discipline.
I have access to career resources (mentors, career services, guidance counselors).
My career goals are aligned with a major in a science discipline.
I see myself using scientific principles in my future job.
I see myself as capable of using my scientific knowledge to understand newsworthy or other important issues.
I have chosen a major that involves science in order to make a difference in the world.
I collaborate with my classmates to address scientific questions.
The science activities I engage in are based on problems I am interested in.
Engaging in science activities helps me see myself as a scientist.
I am hardworking enough to succeed in a science program.
I am intelligent enough to do well in science.
I am self-reliant when studying science (finding resources, managing time, asking questions when I need help).
I am interested in topics in general science or in a specific scientific field (biology or microbiology, chemistry, physics, physical science, astronomy, engineering, environmental, etc.)
I am curious about things that can be explored through science or through the scientific process.
I know how to conduct a scientific experiment/I can identify the stages of a scientific experiment.
I am able to comprehend scientific principles.
I have practical science skills (lab skills, writing hypothesis, analyzing data and results, drawing conclusions).