# STEM Success Scholars: First-year interventions to promote STEM identification in low-income, high-achieving college students in a STEM learning community

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## Abstract

Many first-year, low-income STEM students do not remain in STEM majors past their first year nor do they complete STEM degrees. Our project aimed to support low-income, STEM majors financially and promote their STEM identities by creating a learning community focused on developing positive relationships among students, faculty, and peer mentors. Our research examined how first-year interventions such as a cohort-based STEM-themed first-year experience, peer and faculty mentoring, community meetings, and STEM seminars and conferences provided opportunities for students to (1) develop a sense of belonging, (2) develop competences in biology and math, (3) perform biology and math practices, and (4) be recognized for their competence and performances. Qualitative methods were used collecting and analyzing data from observations of scholars during a first-year experience course, meetings and seminars, and semi-structured interviews. Findings inform how interventions during STEM majors' first year of college can support students' STEM identity.

*Keywords:* STEM identity, peer mentoring, STEM learning community

## Introduction

Many students who develop an interest in STEM fields (i.e., science, technology, engineering, and math) during their K-12 education do not persist in their college level studies and graduate with STEM degrees (Sithole et al., 2017). This is especially true of women, minoritized, and low-income students. Underrepresented minority students enroll in STEM majors at nearly the same rate as White students, but their completion rates are 15% - 24% lower (Riegle-Crumb et al., 2019). Lower completion rates keep them from obtaining lucrative and rewarding STEM careers. The U.S. Bureau of Labor Statistics (2022) forecasts an above average growth (2020-2030) in medical science and mathematics jobs. Medical scientists are expected to grow at 17% with a median pay in 2021 of $95,310, and mathematician and statistician positions are expected to grow by 33% with a median pay in 2021 of $96,280. Biologists with mathematical modeling skills will also be needed to better predict disease origin, spread, and eradication, like that for the COVID-19 outbreak (Jia & Lu, 2020).

However, research suggests that students from low-income backgrounds have a success rate much lower than students who are more financially secure and leave STEM when they drop out of college (Doerschuk et al., 2016). For example, 25% of Pell Grant recipients leave STEM when they drop out of college compared to 18% of non-Pell Grant recipients (Chen & Soldner, 2013; Sweeder, et al., 2021). Students who leave college may find employment in STEM jobs without a bachelor's degree, but these are typically lower paying skilled technician positions (NCSES, 2023). Although, on average, men drop out of college more often than women (24% and 14% respectively), more women switch to non-STEM fields than men (32% and 26% respectively) (Chen & Soldner, 2013). The challenge is to find ways to support low-income and underrepresented students, so they choose to continue with their plan of study leading to a STEM degree.

Developing a STEM identity (i.e., instilling in students a sense that they can understand, use, and contribute to STEM fields) is one of the most important goals of science education (NRC, 2009). Chang et al., (2020) found science identity to be the single-best predictor of students' pursuit of a STEM degree. Having a STEM identity includes the desire to engage in the required learning to become competent in the knowledge and performances necessary to persevere and achieve in their chosen STEM major (NRC, 2009). Many factors contribute to the development and maintenance of a STEM identity including initial achievement and interest. These are important in early stages of STEM identity development but are not enough to sustain students when their STEM studies increase in rigor. The three constructs found to be most important in developing and maintaining a STEM identity are competence in STEM knowledge and understanding, performances of STEM practices and recognition by meaningful others. Individuals must also recognize themselves as people who are capable and can make meaningful contributions in a STEM field. To recognize themselves as belonging in a STEM field, individuals must feel they are competent (they are capable of understanding and using STEM ideas), can leverage STEM practices as ways of learning and solving problems, and can use and contribute to pursuits valued by their community. Along with a desire to be a particular kind of science person, one's science identity is also influenced by larger social structures such as gender, race, and ethnicity (Carlone & Johnson, 2007).

Our project, STEM Success Scholars, ($S^3$), involves defraying the financial costs of college with an NSF S-STEM scholarship and supporting students' sense of belonging and STEM identity through the creation of a STEM learning community. An increase in a family's ability to pay for college improves retention rates of first-year students, and institutional financial aid also increases the likelihood that first-year students return for their second year (Olbrecht, et al., 2016). The $S^3$ program provides our Success Scholars with a 4-year scholarship so they will not need to work while in college and can focus on their studies. The scholarship also gives students time to participate in our learning community activities which included faculty and peer mentoring, community meetings, and participation in STEM seminars and conferences.

This study aims to add to the knowledge base of how specific interventions may affect the math and science identities of low-income students who have historically been marginalized in STEM fields. Given the importance of developing a STEM identity for persistence of underrepresented populations in STEM (Archer, et al., 2010; Barton, et al., 2013; Merolla & Serpe, 2013), there is a need to understand how specific support structures focused on: (1) developing student STEM competences, (2) engaging students in STEM performances and (3) creating opportunities for students to be recognized for their competence and performances, interact with student agency to develop a sense of belonging in and identification with STEM fields.

## STEM Identity Authoring in First-Year STEM Programs

STEM identity authoring, grounded in social practice theory, is a theoretical lens focused on interpersonal interactions during engagement in practice within local and socio-historical structures (Carlone, 2012). A person has multiple identities that are fluid, dependent on their social environment, and are continually changing as a social process (Varelas, 2011). Identities are constructed through experiences and social interaction and become internally conceptualized as positions or roles in society (Hazari, et al., 2015; Stets & Burke, 2003). These identities include both social and personal identities. Social identities are related to social structures such as social group membership while personal identities are related to everyday, individual experiences centered on individuality (Côté & Levine, 2002; Hazari, et al., 2015).

Carlone and Johnson (2007) developed an initial model of science identity around three important constructs: (1) competence - knowledge and understanding of core concepts, (2) performances – shared sets of actions such as ways of talking, using tools that are performed by members of a group based on common purposes and expectations, (Carlone, 2012; Kelly, 2007; Lave & Wenger, 1991), and (3) recognition - of science competences and performances by self and meaningful others.

Science competence is often measured against a priori definitions of what is "good science" (Carlone, 2012; Kelly, et al., 1998); however, what students need to do to be considered competent varies across settings. Competence, then, is not only considered as a trait of the individual but is constructed through their opportunities to participate and demonstrate their competence (Carlone, 2012; Carlone, et al., 2011; Gresalfi, et al., 2009).

Performance of scientific practices include investigative, communicative, and epistemic practices. Investigative practices are those of inquiry such as observation, data collection, problem solving, and testing ideas. Communicative practices include question-asking, generating interpretive inscriptions, and discussions. Finally, epistemic practices include inferring, justifying, evaluating, and legitimizing scientific knowledge (Carlone, 2012).

Carlone & Johnson (2007) in their study of successful women of color in science, discussed three types of science identities: research, altruistic, and disrupted according to the type of recognition they received. Research STEM identities involved recognition by scientifically meaningful others. Altruistic STEM identities found meaningful recognition by others outside of science (e.g., family, friends, community members). Disrupted identities connected to experiences where they felt overlooked, neglected, or discriminated against from meaningful scientific others. For the women in this study, the type of recognition they encountered was the main factor in determining their pathway through science (Carlone & Johnson, 2007).

The three constructs of STEM identity: competence, performance and recognition are influenced by the engagement of the individual in scientific communities of practice. STEM learners need to see themselves as members of a learning community where they can construct knowledge together (Kane, 2012; Olitsky, 2007: Varelas, et al., 2011). Learning is a continual process of forming and reforming oneself through interaction with others. Through our interactions with others in communities of practice we incorporate features of different ideas and practices from how others make sense of phenomena (Varelas, et al., 2011). "As people co-construct their positioning in the social practices in which they participate, they construct views about their and others' competence in terms of this practice's particular characteristics (Greeno, 2006; Gresalfi, et al., 2008) and the framing of their own experience" (Varelas, et al., 2011 p. 828).

Engagement, imagination, and alignment are three modes of belonging important in identity formation (Carlone & Johnson, 2007; Wenger, 1998). It is important to understand how aspiring members engage in a community of practice, how they negotiate, become alienated, or affiliated with the cultural norms (Carlone & Johnson, 2007) and how they imagine themselves in this new community and align themselves with new norms. To persist in their studies of STEM fields, students need to see themselves as belonging in the field and develop a lifelong STEM learner identity. These three constructs combined as a science identity, are often in tension with social structures emphasizing racial, ethnic, and gender identities (Carlone & Johnson, 2007; Hazari, et al., 2015). Similar research on the process of developing a mathematics identity has occurred over the past twenty years and relies on the same dominant theories (Gee, 2000; Holland, et al., 1998; Lave & Wenger, 1991) as for a science identity (Graven & Heyd-Metzuyanim, 2019).

**Learning Community Interventions to Support STEM Identification**

First-year students who participated in learning communities self-reported higher levels of engagement than peers without a learning community experience. They also had higher grades and retention rates and reported studying with peers outside of class more and becoming more involved with academic activities (Engstrom & Tinto, 2007; Shapiro & Levine, 1999; Solanski, et al., 2019; Taylor, et al., 2003; Tinto & Goodsell, 1993; Tinto & Russo, 1994; Zhao & Kuh, 2004). Although there have been few studies of STEM learning communities (Seymour & Hewitt, 1997; Solanski, et al., 2019), they show positive impacts by helping develop a sense of engagement and institutional identification (Gabelnick, et al., 1990; Solanski, 2019) necessary to persevere in rigorous STEM programs (Dagley-Falls, 2009; Solanski, 2019). Marra, et al., (2012) found lowered retention rates among engineering students associated with a lack of: (1) quality teaching, (2) interaction and communication between students and faculty, and (3) a sense of belonging, Small learning communities can help shape students' sense of belonging at their institution by providing highly personalized structure and support (Darling-Hammond, et al., 2009; Sweeder, et al., 2021). Students' sense of belonging in the first semester was found to predict their future interactions with peers and faculty and how their sense of belonging progressed through the first year (Hausmann et al., 2007; Ribera, et al., 2017).

**STEM Identity Support through High Impact Practices.** High-impact practices are strategic educational practices that promote multiple student outcomes (e.g., sense of belonging, engagement, and resilience) (Fassett & BrckaLorenz, 2021; Ribera et al., 2017; Weiss & Fosnacht, 2018; Yeh, 2010). While not all high impact practices have been associated with higher student persistence rates (Fassett & BrckaLorenz, 2021; Johnson & Stage, 2018), faculty participating in learning communities are encouraged to use high impact practices to engage with students in meaningful ways that may promote a greater sense of belonging based on perceived social support, connectedness and mattering (Fassett & BrckaLorenz, 2021; Strayhorn, 2012). Pedagogies such as collaborative and problem-based learning when well-implemented can lead to a better sense of belonging by engaging students and allowing them to learn as equal partners (Smallhorn, 2017; Tinto, 2017). Multiple studies have shown that sense of belonging is associated with persistence and positively linked to achievement (Solanski, et al., 2019; Zumbrunn, et al., 2014), engagement (Solanski, et al., 2019; Wilson, et al., 2015), and student motivation (Freeman, et al., 2007; Murphy & Zirkel, 2015; Solanski, et al., 2019; Strayhorn, 2012).

Koch, et al., (2018) found that STEM-focused FYE's in engineering, science, and math which either integrated literacy or paired with a literacy course were effective in increasing students' learning power. Learning power is described by Crick et al., (2004) as personal power to learn consisting of seven dimensions: (1) changing and learning – the feeling that one can learn and change as a result of the learning, (2) critical curiosity – having the desire to probe a concept deeply, (3) meaning making – actively looking for connections and relating learning to your personal life, (4) creativity – using imagination and intuition, being playful and taking risks while learning, (5) learning relationships – being comfortable learning independently and collaboratively, (6) strategic awareness – actively managing one's own learning, and (7) resilience – persevering through challenges to progress in one's learning processes.

**STEM Identity Support through Faculty and Peer Mentoring.** Mentors provide subject-specific expertise, socio-emotional support, help in setting goals, and act as academic role models for students, four domains found to be important for positive mentoring (Nora and Crisp, 2007; Zaniewski & Reinholz, 2016). Positive mentoring in general can increase student success measures such as, academic performance, social integration, and retention (Campbell & Campbell, 1997; Crisp & Cruz, 2009; Mangold, et al., 2002; Zaniewski & Reinholz, 2016).

Winterer et al., (2020) identified mentoring, including peer mentoring, as a key driver of success for Latinx STEM majors. Peer mentoring can establish a learning community where students learn from each other (LaFee, 2003; Miller, 2000; Sithole, et al., 2017: Smith, 1993). Peer mentoring can provide psychosocial and academic support that results in improved academic performance, confidence, and study skills, that benefits both the mentees and the mentors (Beasley, 1997). Peer mentors can help bridge the communication gap between students and faculty and help mentees develop their communication skills which can also benefit the mentors (Edgcomb, et al., 2010). The peer mentor/mentee relationship is a delicate balance that can benefit both. Mentees can benefit from having a positive role model, help in connecting to the larger community, and through encouragement, advice, and friendship. Peer mentors can benefit by developing friendships in the program, being paid for their time, and developing feelings of accomplishment in helping other students connect to the larger institution. They risk, however, the mentee becoming too dependent on them for help on every problem they encounter in their academics (Colvin & Ashman, 2010; Sithole, et al., 2017). Koch, et al., (2018) found that voluntary mentee attendance at peer mentoring sessions was not as effective as predicted at helping students feel informed and connected to their major and did not increase students' likelihood of persisting. Many students decided against engaging in peer mentoring since it was voluntary, providing evidence that to be effective for at risk students, peer mentoring needs to be mandatory.

**STEM Identity Support through Learning Community Meetings, STEM Seminars, and Conferences.** Zhao & Kuh (2004) found students who participate in learning communities are more likely to interact with faculty, and Maestas, et al., (2007) found students who perceive faculty as having a special interest in them had a greater sense of belonging (Ribera, et al., 2017). Learning communities can show students the collaborative nature of scientific discovery and see their part as a steppingstone to their future in STEM (Edgcomb, et al., 2010; Sithole, et al., 2017). Hoffman, et al., (2002) found students who took advantage of structured academic opportunities felt peers and faculty were more supportive, faculty were more empathetic, and they experienced lower levels of isolation (Ribera, et al., 2017).

## Methodology

This study's goal was to investigate how specific interventions in a learning community may affect STEM identity-authoring in biology and math majors which may lead to retention and graduation in the major. The research is part of a larger multi-year NSF-funded collaborative project among the biology, math, and education departments of a small public liberal arts university in the Northeast region of the United States. The larger project had two goals: (1) to support low-income, academically promising biology and math majors socially, academically, and financially to increase retention and graduation rates, and (2) to transition students to STEM employment or graduate studies. The two main components are a 4-year scholarship of up to $9750/year and participation in a learning community. The learning community incorporated three primary interventions the first year: (1) placement in a cohort-based first-year experience seminar, (2) faculty and peer mentoring, and (3) community meetings, STEM seminars and science-based conferences. All protocols were approved by the Eastern Connecticut State University Committee on the Use of Human Subjects in Research.

**Participants**

Five first-year biology majors were selected for the first cohort so that each could receive an impactful amount of scholarship money. Four of the five students agreed to be part of the educational research component; one research participant withdrew from the university early in the first semester leaving three participants. All names are pseudonyms. (Table 1). All participants met our scholarship criteria:

a. Pell eligible
b. High school GPA greater than 3.5.
c. Declared biology or math major

**Table 1**

*Scholar Demographics*

| Pseudonym | Major | Age | Race | Gender |
|---|---|---|---|---|
| Carl | Biology | 18 | White | Male |
| Elena | Biology | 18 | Hispanic | Female |
| Nora | Biology | 18 | White | Female |

Five peer mentors also participated in the learning community, three each semester.

**Table 2**

*Peer Mentor Demographics*

| Pseudonym | Major | Class | Semester | Race | Gender |
|---|---|---|---|---|---|
| Charlie | Biology | Junior | Spring | White | Nonbinary |
| Gladys | Math | Junior | Spring | Black | Female |
| Jose | Biology | Senior | Fall and Spring | Hispanic | Male |
| Kendra | Biology | Senior | Fall | White | Female |
| Liana | Biology | Senior | Fall | White | Female |

## Study Design

This multiple case study (Stake, 2006) followed three low-income biology students selected for an S-STEM scholarship through their first year of college. The target phenomenon was how participation in the learning community and its interventions (i.e., STEM-focused first year experience course, faculty and peer mentoring, community meetings, and STEM-focused seminars and conferences) affected the student's STEM-identity authoring. We used purposeful sampling based on student criteria needed to obtain a scholarship in our program to explore the experiences of students in the program, (Creswell, 2013). Qualitative methods were used throughout. The research questions were shaped from the theoretical framework of STEM identity authoring:

1. How do the experiences of engaging in a STEM learning community (e.g., STEM-focused first year seminar, faculty and peer mentoring, and STEM seminars and career workshops) support STEM identity authoring of the students?
    a. How do the different support activities contribute to the development of disciplinary competence and performances?
    b. How do the different support activities provide opportunities for recognition of competences and performances?

2. How do social structures (e.g., group level norms, positioning) interact with identity authoring to support or constrain student agency?
    a. How do interactions between faculty mentors and mentees support the ongoing process of STEM identification for faculty mentor and mentee?
    b. How do interactions between peer mentors and mentees support the ongoing process of STEM identification for peer mentor and peer mentee?

**Data Collection Procedures.** Data collection included observations of S$^3$ scholars in the FYE course, during community meetings, STEM seminars, and an undergraduate science conference. Individual semi-structured interviews were conducted with scholars and peer mentors following Seidman's (2013) three interview protocol modified to span the academic year. The initial interview, conducted early in the first semester, focused on the participants' historical STEM identities. The second interview, early in the second semester, focused on the participants' experiences in the learning community and participation in the different interventions. The final interview, at the end of the second semester, asked the participants to reflect on their overall experiences throughout their first year in the learning community. Interview questions were open-ended allowing participants agency to construct meaning of their experiences while recognizing that meaning is shaped by background and prior experiences (Creswell, 2013). Interviews were transcribed and initially coded according to the constructs of STEM identity authoring (Carlone & Johnson, 2007) but allowed for emergent themes to surface. Artifacts such as FYE classwork (e.g., essays and research papers) and email communications were used as secondary sources.

**Data Analysis Procedures.** Data were analyzed through an iterative process consisting of three stages. The first stage involved an initial orienting pass through the data reviewing observation notes and transcribed audio recordings of interviews for relevant episodes along with preliminary coding and writing analytic memos. In Vivo Coding – using the participants' own language in words or short phrases - was used with the interviews to better attune to the participants' perspectives and actions (Saldana, 2016). Data were examined during the second stage to identify "units of meaning" (i.e., statements seen to illuminate the researched phenomenon" (Creswell, 1998; Groenewald, 2004) related to the constructs of STEM identity authoring (e.g., competence, performance, recognition) (Carlone, 2012) and the program interventions (e.g., FYE course; faculty and peer mentoring; meetings, seminars, and conferences). In the third stage of analysis, units of meaning were reviewed considering the research sub-questions to develop themes representing clusters of salient units of meanings to answer the research questions (Groenewald, 2004). Findings were ordered to determine those most important for understanding STEM identity authoring in our learning community participants in relation to the different themes. These themes represent our findings which are discussed next.

## Findings

Overall, we found the learning community interventions to be important for STEM identity authoring. The first-year experience course developed students' competence in scientific literacy skills and critical thinking. Course participation, faculty and peer mentoring provided opportunities for recognition of competence and performances, building relationships, and creating a sense of belonging among the scholars. Our three initial findings are discussed below.

### Finding 1: The STEM FYE Course Supported STEM Identity Authoring

The Scholars emphasized that they found the FYE course's focus on how to distinguish real science from fake valuable and relevant to their lives, especially in developing competence in foundational science and math concepts (e.g., the nature of science, effects of cognitive biases, statistical manipulation), and performances (e.g., critical thinking, evaluating, and communicating scientific information).

> The idea of personal biases and critical thinking that learning how [to] tell real information from fake information and all the different ideas that advertisers use, and everyone uses to try and convince people of something that it's not entirely actual. So, I would say that learning how to critically think and disparate disparities between what's real and what's not, has been really important. [Carl]

Students critically evaluated articles, websites, and advertisements to determine if information they found was based on real science or pseudoscience. Pseudoscience as defined by the NSF are "claims presented so that they appear [to be] scientific even though they lack supporting evidence and plausibility" (Shermer 1997, p. 33). In contrast, science is "a set of methods designed to describe and interpret observed and inferred phenomena, past or present, and aimed at building a testable body of knowledge open to rejection or confirmation" (Shermer 1997, p. 17) (*NSF*, 2002).

> I found science versus pseudoscience most universally helpful… that kind of made you take a step back and look at different perspectives of worldly things like commercials and being persuaded with different things. And what is true and what is not true and seeing when you're having a conversation with [a] person you can actually pick these certain things out now. [Nora]

Along with critical thinking to determine the validity of science concepts, and the effect of cognitive biases, the FYE course exposed the STEM students to the ways math is used to provide supporting evidence of scientific claims, and how mathematics can be manipulated to misinform. This encouraged the students to also think critically about data and how it is interpreted.

> Oh, it was the projects that we did, the doing the research… Where we had to think about our answer and then make it better… it was more of brainstorming and more evidence based… The [FYE] class taught us that we can always take the evidence and manipulate it. [Elena]

The Scholars found these skills foundational to being a scientifically literate person and were able to connect these performances to their daily interactions and conversations with other people.

The Scholars also expressed that the STEM FYE course was significant for them because it promoted the formation of relationships between themselves, and with the faculty mentors teaching the course, “Yeah, I just feel like the most important one is like how welcoming the community [FYE class] is and how like, inclusive, it is.” [Nora]. The scholars had a set time each week where they interacted with each other in the course and got to know each other and recognize different strengths in themselves and their peers. Both Nora and Carl recognized their ability to speak up in class as a strength and both were observed doing that in the FYE class.

> I would say that my biggest contribution to the program as a whole so far would be the way that I can speak up in classes and speak my mind and say what my opinion is, and I'm not afraid to answer question, even if it might not be 100% right. [Carl]

Elena appreciated how Nora could take the lead and be the first to speak out. This was something that was difficult for Elena. “What I found helpful is Nora. She's like the one that talks, is the first one that makes it open and comfortable for us to voice our opinions, like the leader.” [Elena]

Elena also found it difficult to ask for help. Nora, however, was comfortable asking for help and recognized this as a strength that could help other students, “I think maybe like seeing the drive I have to get help with like certain subjects could maybe help them.” [Nora]. The FYE class was an opportunity for the scholars to build relationships with each other and support each other with their various strengths.

This support continued to some extent after the course was over. Although all the scholars were no longer in the same class together, each scholar was in a course with at least one other scholar. Nora expressed how having built the relationships with other students and the $S^3$ faculty continued to support her the following semester:

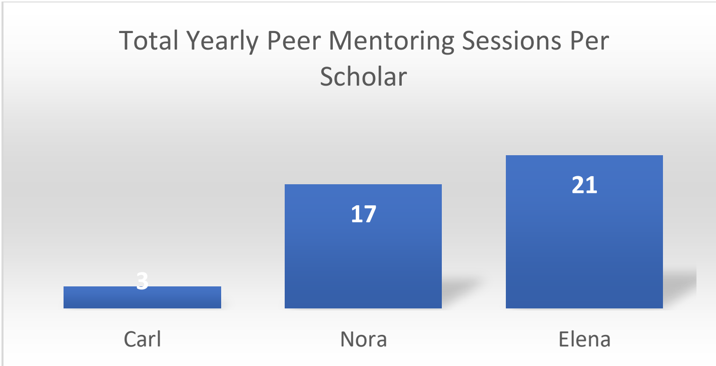
> I feel as though there's a lot more support is what it is and especially with the having the other student. Especially seeing them around campus and being able to get help with them… I felt like I was more supported, well-rounded because I had you like the faculty of the $S^3$ program. [Nora]

While the course was only one semester long, it helped the students to build relationships with other students and faculty that continued to support them throughout their first year.

**Finding 2: Peer Mentors Supported STEM Identity Authoring**

Meeting with peer mentors created a space for the scholars to receive recognition for many aspects of their identities including competence and overcoming personal struggles. Scholars met with peer mentors on a rotating schedule and enjoyed time with each one. The mentees found these meetings important for learning stress reduction skills, receiving encouragement, and soft skill support. Scholars used peer mentoring as a social support for their transition to college more than for academic assistance. Peer mentoring appeared especially important as a support for the scholars’ mental well-being, although more so for Elena and Nora than Carl. The number of meetings sessions varied from two for Carl to 21 for Elena.

*Figure 1: Total Peer Mentoring Sessions Per Scholar*




Elena met with the peer mentors the most (21 times). As a first-generation college student, she found the peer mentors valuable resources in helping to navigate her first year at college. She enjoyed meeting with different peer mentors as each focused on different aspects of her life as a new college student. One mentor helped her keep track of her goals, another worked to reduce her anxiety levels, and the third offered structured study time.

> I feel like the peer mentors did help us out a lot. So, Jose as I said, always kept on asking us about goals and how we were doing. Kendra would take me on walks to kind of be relief of work and Liana would give us time to do work during our meeting and she would be there for help. [Elena]

Nora also met with the peer mentors regularly throughout the year (17 times). Nora was open in discussing her challenges with mental health issues, specifically anxiety.

> It's like a learning curve going to college the first semester, like my anxiety with around classes. I was like, am I even fit to go to college and then of course it was just like an anxious moment, but I would say I would like to say that there was a positive. But I feel like the positive is that it kind of gave me thicker skin and like at the end of the day I still know I wanna do biology. [Nora]

While expressing that having structured study times was beneficial, what Nora really found helpful was having someone to talk to about the challenges of the first year of college and any other issues she was concerned about.

> But there's also other outside factors that we do deal with, like on a daily basis and having that support from them and knowing that Jose has always said we don't always have to talk about school. He's like, even if you need someone to talk to like just about anything… [Nora]

Nora found the peer mentors helpful in navigating her first year by acting as a sounding board while making decisions and especially in helping to relieve her stress and anxiety.

> They [peer mentors] can help with certain decisions that we have to make and even just having to talk to them about the stress and anxiety that we're under, that is even helpful. Just being able to go to them and they understand it and all that stuff. So overall, I would say that this [meeting with peer mentors] has been immensely helpful. [Nora]

Carl met much less with the peer mentors (3 times). Although he expressed that having peer mentors available to him was valuable, his lack of participation in peer mentoring does not appear to support this. Carl expressed that what he found most important was the recognition from the peer mentors that he was capable and able to get his work done.

> I think being able to come to them [peer mentors] and they relate, and they know and they're able to help you be like, alright, you got this, we can help you… We're not asking them to do our homework. Our homework's for us, but if we need a nice pick me up they're there to be like, yeah, you got this because we know they've been through it. [Carl]

It is notable that Carl played on a varsity sports team where he felt part of a smaller community that also often created conflicting demands on his time. Although Carl had more demands on his time, he never expressed issues with anxiety and stress as the other participants did.

**Finding 3: Peer Mentor Meetings, and Attendance at Seminars and Conferences Supported STEM Identity Authoring**

The scholars found their developing relationships with the upper-class peer mentors was something that happened because they were part of our learning community. Through interacting with peer mentors, the scholars were given a preview of what their near future could be like.

> And another thing is that they [peer mentors] have, they have their experience and they're going through what we're going to be going through in the next few years. And so just their experience and being able to say hey, this is what's in your future. Umm this is this is what you should do. [Carl]

The peer mentors were able to speak about their experiences progressing through the major and how they could now view them from a different perspective as someone who successfully navigated the four years. The scholars were able to gain a different perspective about what they were experiencing and see themselves as also being able to successfully persevere through their four years.

> I meet with Jose usually once a week and we've kind of just gotten on to a very friendly basis and especially when the school year kicks up, we start doing study sessions together. We will just spend time in the library for a little bit. I find it very helpful, especially seeing it from like a senior's POV (point of view). [Nora]

Of the three scholars, Elena attended the most biology seminars on campus and the Eastern Colleges Science Conference where undergraduate students present their research:

> For me it was a new experience 'cause I had never been to the conference like that. And seeing a whole bunch of students having their projects in front of scientists that are high above us look at them was interesting. It was a cool experience, and we get to have contact with those people... It showed me what I might be doing in the future. [Elena]

Elena found the seminars and conferences provided a window into her possible future and helped her visualize herself involved in research. Visualizing themselves as upper-class students or researchers is a form of self-recognition that could help support the scholars' STEM identity. The other two scholars were unable to attend the conference missing an opportunity for self-recognition of their future in STEM which may have further supported their STEM identities.

## Discussion

One of the most important goals of science education is to instill in all students a sense that they can understand, use, and contribute to STEM fields (i.e., develop a STEM identity) (NRC, 2009). The S$^3$ program sought to add to the knowledge base of how specific interventions may affect the math and science identities of low-income students who have historically been marginalized in STEM fields. Given the importance of developing a STEM identity for persistence of minoritized populations in STEM (Archer, et al., 2010; Barton, et al., 2013; Merolla & Serpe, 2013), there is a need to understand how specific support structures focused on: (1) developing student STEM competences, (2) engaging students in STEM performances and (3) creating opportunities for students to be recognized by meaningful others and by themselves for their competence and performances, interact with student agency to develop a sense of belonging in and identification with STEM fields.

Our findings support previous findings that FYE courses which serve as gateways to core courses in the major can be important motivators for persistence in the major when the curriculum is perceived by students as having meaningful applications to relevant issues that concern them (Kahu, et al., 2017; Tessema, et al., 2012; Tinto, 2017). Our scholars are all low-income, but not all are underrepresented in STEM. Carl, as a White male, is not underrepresented when it comes to STEM and has privileges due to his race and gender (NCSES, 2023). Nora, as a White female, is underrepresented in STEM, but has privilege due to her race. The two students were recognized as having agency to speak up in the course by Elena who as a first-generation Hispanic female is underrepresented in STEM and lacks privilege in these spaces. Nora also recognized herself as someone willing to seek out help which has been found to be a challenge for many first-generation students (Payne, et al., 2021). Asking for help may be hindered by stereotype threat and self-stigma in first generation and minoritized students (Payne et al., 2021; Winograd & Rust, 2014). Having a peer emphasize the importance of seeking help may work to overcome such reticence. We created this program to assist low-income students to persevere in their STEM education, graduate, and enter a STEM career. There may be value in creating integrated learning communities that include more privileged students who act as role models for behaviors such as speaking up in class and asking for help.

Our findings add to similar findings that successful peer mentoring creates a learning community where students support each other in academic and nonacademic ways (LaFee, 2003; Miller, 2000; Sithole, et al., 2017; Smith, 1993). We found one of the most important roles peer mentors played for our scholars was in stress relief and encouragement (recognizing that students could handle the stressors of a first-year student). Peer mentors can act as a bridge between first year students and faculty members and help to create a sense of belonging in the disciplinary field and larger community (Colvin and Ashman, 2010). Our one scholar who did not participate much in peer mentor meetings, program meetings, and seminars played on a varsity sports team. As a White male, he also didn't have the types of challenges that women and minoritized populations encounter in maintaining their STEM identities. While seeming eager to participate in our learning community, his attendance was low often due to obligations to his team. He may have found the supportive community he needed through sports.

Our findings support similar findings of the importance of positive recognition of competence and performances in STEM fields (Barab and Hay, 2001; Carlone & Johnson, 2007; Markowitz, 2004) but broaden recognition to include self-recognition as visualizing oneself in a possible future. Developing relationships with upper class students in the same field of study provided an in-depth view of what they could expect in the next few years at college and a sense of recognition that they could also be successful. Attending the undergraduate research conference also provided a clear view of how they could soon be involved in research and recognition of a possible successful future in STEM. Participation at research conferences is something we should focus on in the future to provide more opportunities for our scholars to envision themselves in STEM.

## Conclusion

Disciplinary learning communities can provide students with interactions and supports to allow them to visualize their future in STEM more realistically. Through interactions with peer mentors, faculty members, and attendance at seminars and conferences, they can break the isolation many first-year STEM majors feel by allowing them to see their studies as a steppingstone to their future in scientific discovery (Edgcomb et al., 2010). Peer mentors can be a powerful force in these communities. Not only can they provide academic support, act as role models and encouragers, but they provide a window into the mentee's possible future. For a system-wide implementation of peer mentoring, funding sources for peer mentor stipends need to be ascertained.

The scholars' STEM identities were supported by the interventions implemented in our learning community. The first-year experience course gave the students opportunities to demonstrate competence, engage in scientific practices, and be recognized by their learning community. It also gave them the opportunity to get to know the program faculty who also acted as their mentors. Regular interactions with peer mentors helped them to recognize themselves as belonging in STEM and see a clearer picture of what their future holds. Attendance at STEM seminars and conferences further allowed students to visualize their path forward in STEM.

The development and maintenance of a STEM identity is an essential aspect of all science education. Specifically, educational researchers, science program designers and practitioners, and those involved in equity and diversity issues in STEM education need to understand the effectiveness of specific interventions such as those in our learning community; cohort-based first year experiences courses, peer mentors, community meetings, and seminars designed to support STEM identification.

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## Author Biographies

**Dr. Laura Rodriguez** is an associate professor of education specializing in K-12 science education. She earned her B.A. in biology degree from Boston University and her Ph.D. in curriculum and Instruction from the University of Connecticut. Her research is on STEM identification in formal and informal science learning.

**Dr. Kim Ward**, a Professor of Mathematics at Eastern Connecticut State University, earned her Ph.D. from Old Dominion University. As a first-generation college student, she recognizes the power of teaching and mentoring and has a strong affinity for working with college preparatory programs and teaching first-year and sophomore courses.

**Dr. Elizabeth Cowles** earned her B.S. degree from Cornell University and her Ph.D. in biochemistry from Michigan State University. She teaches biology at Eastern Connecticut State University, her academic home since 1997; she won the University level Trustees Teaching award and is an Eastern distinguished faculty member.

**Dr. Carmen R. Cid** is Professor of Ecology and Dean of Arts and Sciences emerita at Eastern Connecticut State University and Fellow of the Ecological Society of America. She has been nationally honored for her leadership in curriculum development and career enhancement programs to increase the diversity of STEM scientists.

**Dr. Barbara Murdoch** is a Professor of Biology at Eastern Connecticut State University. Her expertise lies in Stem Cell Biology and Cell Communication, with a keen interest in antibiotic resistance and the microbiome. Her education research seeks to understand how to better support student learning, retention, and persistence in STEM.

**Appendix A: Science vs. Pseudoscience Syllabus**

**Course Description**

This course will examine a wide range of unusual claims and paranormal phenomena with the goal of learning how to critically examine "strange and unusual" things. We will consider the features that characterize science and discuss how pseudoscience deviates from these. The class will investigate some of the psychological issues associated with perceptions and belief - *e.g.,* misinterpretation of data, biased perceptions, fallacies of thought, and illogical behaviors - to see how these can lead to accepting/embracing unsubstantiated claims. Students will learn about the scientific methods in designing experiments to test extraordinary claims and to investigate paranormal phenomena. The class will explore a variety of unusual phenomena and examples of pseudoscience, including such topics as astrology, alien encounters, ESP, channeling, near-death experiences, brain tuning, homeopathy, electromagnetic therapy, psychic "powers", therapeutic touch, and "creation science".

**Student goals in FYE 100**: By the end of the course, students will be able to:

1. Recognize the many and varied ways of pursuing knowledge in an academic environment.
2. Understand the roles of claims, evidence, and sound reasoning in academic pursuits.
3. Effectively communicate with others: orally, visually and in writing.
4. Find and employ accurate and relevant evidence to support a position.
5. Respect others and points of view dissimilar from one's own.
6. Demonstrate essential intellectual traits such as integrity, empathy, perseverance, and fairness, empathy.
7. Develop college skills as presented through the Learning Management System. (LMS)

**Science vs Pseudoscience Class Schedule Topics/Learning Modules (LM)**

| Week | Topic | University Learning Modules |
|---|---|---|
| 1: | Course introduction and why understanding pseudoscience matters | LM 1: Accessing Important Information, including Health & Counseling Services |

| | | |
|---|---|---|
| 2: | The nature of science; pseudoscience, and “fringe” science Distinguishing Science from Pseudoscience | LM 2: Time Management |
| 3: | Where human thinking goes awry: perceptual, motivational, and social biases | LM 3: Library Orientation |
| 4: | Fallacies in logic and noncritical thinking | LM 4 Notetaking & Test-Taking |
| 5: | Misinterpretations of association, chance, and probabilities | LM 5: Critical Thinking |
| 6: | Why science? Ways of knowing and understanding | LM 6: Creativity |
| 7: | Methods of science: gathering evidence; experiment design | LM 7: Preparing to Meet with Your Advisor |
| 8: | Analyzing extraordinary claims Discuss Reading: The Fine Art of Baloney Detection, Carl Sagan | |
| 9: | Pseudoscience Critique presentations: critique of an article, web site or advertisement promoting a pseudoscientific idea, with identification of error and biases | LM 8: Career Development |
| 10: | Pseudoscience Topic Presentations: report to class on some topical or interesting pseudoscientific idea from news, advertisement, personal experience, | LM 9: Critical Reading |
| 11: | Planning Group-led presentations of specific pseudoscientific or paranormal areas | LM 10: Critical Thinking |
| 12: | Group-led presentations of specific pseudoscientific or paranormal areas | LM 11 Financial Literacy |
| 13: | Group-led presentations of specific pseudoscientific or paranormal areas | |

| | | |
|---|---|---|
| 14: | Planning: Create your own hoax: Develop and explain a pseudoscience claim and the arguments and reasoning to support the claim | LM 12: Finals, Course Evaluations and Textbook Returns |
| 15: | Present Hoaxes | |

**Assignments**

1. Response papers (2): short (2 pages at most) critical/analytical response to specific readings or presentations.
    - Paper 1 respond to the paper, video, and presentation on science and pseudoscience.
    - Paper 2 Critical/analytical response to cognitive biases and logical fallacies in scientific arguments:
2. Short report: 5-min report to class on some topical or interesting pseudoscientific idea from news, advertisement, personal experience, etc.
3. Pseudoscience Critique: Provide a critical analysis of a pseudoscientific or paranormal topic. Provide background information (history, literature review); both believer and skeptic interpretations of the idea or phenomenon; a summary and critique of available evidence; and your reasoned conclusions on the issue. Class presentation on paper.
4. Group Pseudoscience topic analysis and Presentation: present a critique of an article, web site or advertisement promoting a pseudoscientific idea, with identification of error and biases.
5. Create your own Hoax Group Activity: Develop and explain a pseudoscience claim and the arguments and reasoning to support the claim. Develop a website, advertisement and present to class.

## Appendix B: S$^3$ Peer Mentoring Program

### Peer Mentor Qualifications:

The mentors must be active within the university community, knowledgeable about campus resources, and understand campus policies.

1. Achieved at least sophomore standing and have a 2.5 GPA or higher.
2. Recommendation by a faculty member who recognized their:
   - Ability to interact with people.
   - Strong interest in helping students achieve academic success in their major.
   - Follow through on commitments.

### Peer Mentor Responsibilities

Provide support in academics, soft skills (e.g., communication, adaptability, leadership, teamwork, time management, emotional intelligence, organization, collaboration) and navigating the college experience.

All peer mentors must agree to and/or participate in the following:

1. Work an average of 4 hours per week.
2. Attend peer mentor training sessions.
3. Meet weekly with scholars and complete mentor meeting log form.
4. Meet with S$^3$ faculty as required.
5. Assist with building a robust learning community by encouraging scholars to get involved with activities offered by the University and the S$^3$ Program.
6. Attend S$^3$ activities as required.
7. Provide social and academic support to scholars.
8. Serve as role models by upholding all the rules and regulations of the University, including academic integrity.

9. Maintain strict confidentiality about information shared between the Peer Mentor and scholars and with the S$^3$ faculty.
10. Work as a team with the scholars, fellow peer mentors and S$^3$ faculty; fulfill peer mentor responsibilities with respect and consideration for all team members; and maintain the relationship of "mentor" to all their mentees.

**Peer Mentor Benefits**

- Paid position that must be reapproved each term.
- Develop ability to work effectively within a team.
- Develop leadership skills and self-confidence.

**Peer Mentor Training**

Format: Online delivery format through faculty-made recorded videos

Process:

1. Peer Mentors meet with faculty member designated as peer mentor trainer for introduction to the program.
2. Peer mentors watch video and progress at their own pace within a set timeframe.
3. After viewing the videos, the peer mentors receive, in both electronic & hardcopy format, homework and quick reference handouts. Both documents serve as quick reference guides when needed and are not evaluated.
4. The peer mentors then complete an online self-assessment through Microsoft Forms and an evaluation of the mentoring modules.

For our first year, peer mentors completed one module on mentoring relationships and skills. The module focused on:

- Communication styles
- Open-ended questions
- Active listening

- Non-verbal communication
- Empathy
- Communication blocks
- Values clarification
- Campus and Community Resources

We divided the module into 5 parts each with an accompanying video and handouts. The videos covered the following specific topics:

1. Mentoring Relationships & Skills Part I
    - Aspects and Value of Mentoring Relationships
    - Goals of Mentoring – support, validation, empathy, skills and strategies
    - Difference from other student support networks
2. Mentoring Relationships & Skills Part II
    - Mentoring skills: Verbal and nonverbal communication skills
    - OARS model (open-ended questions, active listening, reflection, summarize)
    - Nonverbal – body language, attending behaviors, voice
3. Mentoring Relationships & Skills Part III
    - Empathy and vulnerability
    - Mirroring
    - Trust and Rapport
    - Communication Block
4. Mentoring Relationships & Skills Part IV
    - Strategies to build trust and rapport
    - Mirroring

- Self-Disclosure

5. Mentoring Relationships & Skills Part V

- Resources and Referrals
- Approach, educate and encourage, refer

Based on: Dineen, M., & Condra, M. (2016). M2 Peer Mentoring Program: Training Manual. Kingston Ontario, Queen's University.