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Integration Of Utilitarian Scientific Literacy Modules Improve First-Year HBCU STEM Student Experiences

Christopher Chambliss
Emory Univ.
School of Medicine

Lino Guajardo
HBCU STEM-US Research Center

Zsanai Epps
HBCU STEM-US Research Center

Adrian Neely
HBCU STEM-US Research Center

Brittany Chambers
HBCU STEM-US Research Center

Lycurgus Muldrow
HBCU STEM-US Research Center

Joann Powell
Clark Atlanta University

Abstract

Attrition in STEM remains a concern for universities across the US, as the nation struggles to keep up with global demand for a well-trained STEM workforce. Attrition amongst underrepresented student populations is of particular concern as retention rates are statistically lowest among these groups. As such, the US struggles to fully tap into its greatest potential advantage, a diverse STEM workforce. However, HBCU's have been at the forefront of these efforts since the early 19th century. Through this report we quantitatively assess first-year HBCU STEM student perceptions of utilitarian scientific literacy modules and their ability to improve reactive coping outcomes with the aim of further increasing retention of diverse student populations in STEM.

KEY WORDS

STEM Education, Scientific Literacy, HBCU, First-Year Seminar, Freshman, Biology, Student Experiences

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Nationwide, universities face continued concerns with student enrollment, performance, retention, and attrition, particularly within the Science, Technology, Engineering, and Mathematics (STEM) fields (Sithole et al., 2017). According to analysis conducted by the U.S. Department of Education, National Center for Education Statics, between 2003 and 2009 about 28% of bachelor's degree students entered a STEM field of which biological/life sciences is the most popular field attracting 11% of all students (Chen, 2009). Of these entering STEM students, 48% had left the STEM field by the end of the analysis with roughly half the students leaving the STEM major for another non-STEM major and the remaining half leaving college before obtaining their degree. These statistics become even more alarming amongst minority student populations who are disproportionately underrepresented in STEM degrees and tend to face social and economic barriers hindering completion of their post-secondary education (Carver et al., 2017). Together, the poor retention of students regardless of underrepresented status, has placed the United States among those with one of the lowest ratios of STEM to non-Stem bachelor's degrees in the world, increasing concern for the ability of the United States to compete in the global economy and increasing efforts to raise the number of students obtaining degrees in the STEM field (Oliss, 2023).

Increased Demand for Diversity in STEM

A major focus of these efforts lies in strategies aimed at increasing diversity within STEM education and careers. The National Science Foundation Director, Sethuraman Panchanathan, states diversity as "America's unique advantage in science and technology", as it is known to broaden the overall talent pool; encourage innovation;

enrich problem solving capabilities; and improve public trust, perception, and engagement with STEM entities (Smith-Doerr et al., 2017; Statistics, 2023). At the forefront of these endeavors remains Historically Black Colleges and Universities (HBCUs) which, despite making up only 3% of the country's colleges, produce over 25% of African American STEM graduates (Owens et al., 2012). This includes 40% of all Black engineers and 70% of all Black physicians. This does not, however, come without its challenges. Factors that prevent African Americans from succeeding in STEM are present before, during, and after a student earns their degree. For example, as many as 72% of Black students take on student loans in college as opposed to 56% of their White counterparts and the percentage of Black students who received Pell Grants was more than double that of White recipients (Price, 2004)class, and student loans</title></titles><dates><year>2004</year></dates><publisher>Lynne Rienner Publishers</publisher><isbn>1588262162</isbn><urls></urls></record></Cite></EndNote>. Along with financial barriers, recent analyses from the Education Trust and Equal Opportunity Schools demonstrate that though many minority high school students voice interest in going to college to pursue a career in a STEM field, less than 3% are enrolled in any AP STEM courses (Patrick et al., 2022). This can hinder college preparedness and often results in an impaired sense of STEM-oriented self-construal, or scientific identity. Despite these challenges, HBCUs have continuously proven their ability to recruit and retain African American students, demonstrating their capacity in strengthening the STEM workforce. This resilience further highlights the importance of concerted efforts aimed at improving HBCU STEM student experiences to ultimately increase retention and graduation rates.

Can Scientific Literacy Improve Diverse STEM Student Outcomes

A large part of preparing minority students for success in STEM is providing the resources and guidance they often lack long before enrollment in college. The Scientific Literacy modules focus on the teaching of utilitarian scientific literacy to get to the core of what it means to be a scientist. They contain lessons including developing a growth mindset, understanding the scientific method, communicating science, and STEM careers/STEM career preparation (full description in method-

ology). Reports from these courses have shown promising effects in increasing first-year STEM student retention and student attitudes towards their scientific prowess (Chambers et al., 2019). Individual Scientific Literacy modules have further been assessed for their utility including their newest module containing an online automated research simulation case study which proved especially beneficial during the pandemic realizing the difficulty some universities may have with acquiring materials sufficient for an in-person research experience (Chambers, Neely, et al., 2022). Likewise, there is a multitude of research as to the personal and academic advantages of developing a growth mindset for both STEM and non-STEM students at the primary, secondary, and post-secondary levels (Claro & Loeb, 2019; Limeri et al., 2020). Students who have received such utilitarian scientific literacy training tend to show higher order thinking skills and research self-efficacy and report an increased feeling of academic preparedness (Rahayu, 2017). Training in scientific literacy has shown additional benefit to at risk students as defined by pre-college assessments and GPA (Chambers et al., 2019). It is for these reasons that we partnered with the Scientific Literacy Center to adapt these modules for use at Clark Atlanta University. For this investigation, we worked with the Morehouse Scientific Literacy Center (scientificliteracycenter.org) to implement several of their Scientific Literacy Modules into our curriculum in the Department of Biological Sciences at Clark Atlanta University (CAU), an HBCU within the Atlanta University Center Consortium, with the overarching objective of improving student outcomes. After doing so, we assessed student attitudes and experiences in the course to ask and answer questions of 1) What are students' background risks that prevent them from achieving academic desires? 2) What are the students' stresses? How and why does the curriculum support stresses? 3) Are adaptive mindset coping mechanisms being chosen by students? 4) Does the course help the emergence of positive identities? and 5) How does the curriculum contribute to students' productive academic and life outcomes?

The Benefits of First-Year Experiences: Implementing Our Scientific Literacy Modules

The use of these modules has been well cited by the Scientific Literacy Center in several formats including a summer bridge program, an online course, flipped classroom, and college preparedness instrument (Chambers, Lowe, et al., 2022; Chambers et al., 2021; Chambers, Neely, et al., 2022; Chambers et al., 2019). In determining the most appropriate format for module delivery at CAU, we evaluated both pre-existing literature and our objectives to include implementation of the Scientific Literacy Modules in a First-Year Biology Seminar course as the most viable option.

Many students, even those who enter college with strong academic backgrounds, may still lack the skills and coping mechanisms needed to navigate their new academic landscapes (Hollander, 2017; Scott et al., 2010). First-year experience courses, or first-year seminars, have proven widely effective in supporting the high school to college transition for freshmen students of all backgrounds (Kift, 2015). The primary objectives of these courses are to improve academic performance, foster social development, and enhance persistence and degree completion; all shared objectives of the Scientific Literacy modules. Additionally, these courses cultivate a sense of campus community by providing opportunities for student interaction with both faculty and peers. Research has shown that students who participate in first-year experiences, particularly those in STEM fields, are more likely to persist in their majors and graduate on time (Dika & D'Amico, 2016). The 2016 US Department of Education WWC Intervention Report shows that 52% of 4-year colleges require first-year experience courses for all incoming freshmen, and those who participate in first-year experience course show a 6-point improvement in general academic achievement and a 9-point improvement in degree attainment indices (Clearinghouse, 2016).

Additionally, implementation of interventions within a degree-specific first-year experience course has unique advantages including the ability to be tailored to a specialized audience. Though CAU, like many HBCU's, has a pre-existing first-year biology seminar course, its design permits seamless integration of the Scientific Literacy modules as they align with the seminar's standing learning objectives. By integrating the two curricula, we aimed to harness the benefits of each course and maximize their positive effect on self-perceived student outcomes. This report highlights the implementation of 12 Scientific Literacy Modules within the First-Year Biology Seminar course at CAU and analyzes its effects on student outcomes including academic skillsets, career preparedness, STEM-Oriented self-construal, and attitudes towards retention in STEM via qualitative assessment of firsthand student accounts.

Method

Scientific Literacy Modules

The integrated Scientific Literacy portion of the course consisted of 12 stand-alone modules entitled:

- Scientific Literacy Defined
- Why Scientific Literacy is Important
- Scientific Literacy and College Retention
- Growth Mindset
- How the Discovery Process Works, Parts I and II
- The Scientific Method
- Research Simulation Case Study
- Careers in STEM
- Research Experience for Undergraduates
- How Science is Communicated, Parts I and II

Each of these modules contains a professionally produced video lecture with accompanying slides, active-learning activities, and a quiz. Considering that there are

various contextual factors that may affect a students' general accomplishment in the STEM major, this course builds from the ground up to thoroughly provide every student with the fundamental information, skills, and disposition expected to guarantee success. As students complete each individual module, they are exposed to skills needed to persist in their respective STEM fields. From the student-centered learning approach used throughout the course, every student is granted the opportunity for a personalized, engaging, and informative experience that allows them to identify their own unique skills and capabilities. Through the incorporation of a research simulation case study and other supporting activities, they are able to take ownership over their learning, build a scientific identity and increase their self-efficacy. Additionally, the course exposes students to a variety of information on career options, study habits, research opportunities and the importance of a growth mindset. Full descriptions of each module along with its online materials can be found at scientificliteracycenter.org.

Course Format

The 12 Scientific Literacy modules were integrated into one section of a pre-existing First-Year Biology Seminar course, meeting once weekly (75 mins) for a 15-week semester (1 credit-hour). A total of 10 class periods were dedicated to instruction of the Scientific Literacy modules and the remaining 5 sessions were reserved for instruction of standardized seminar materials (i.e., campus resources, financial aid, advisement, registration, and the CAU Career Fair). Each Scientific Literacy module required both online and in-person participation. Students were expected to complete viewings of the online videos and slide shows for each module through CANVAS before the in-person classroom meeting. Class sessions were then used for open discussion, group activities, and review. Lastly, each chapter ended with a short, 3-5 question quiz (online) that was completed before moving on to the next module. A small number of modules included out of class activities which were also due before beginning the next module. Grades were assigned based on quiz averages and completion of module activities.

Course Participants

The student population focus for this study included all first year Biology majors attending Clark Atlanta University. The students were automatically enrolled in either the integrated First-Year Seminar course including scientific literacy modules (1 section), or the previously existing First-Year Seminar course without scientific literacy modules (4 sections). The integrated First Year Seminar course section contained 44 students, all African American, only one of which were male. The four control sections of the First-Year Seminar course were of similar student size and demographics. All studies were reviewed and approved by Morehouse and Clark Atlanta Universities' Institutional Review Boards.

Focus Groups and Qualitative Analysis

Upon conclusion of the semester, four focus groups were conducted including: two focus groups for students who completed the integrated First-Year Seminar Course section WITH Scientific Literacy Modules (FYSSL), and two focus groups for students who completed the standard First-Year Seminar Course section WITHOUT Scientific Literacy Modules (FYS). In total, 12 students attended the FYSSL focus groups and 4 attended the FYS groups (see Discussion/Limitations).

All focus groups were conducted via Zoom, led by two neutral co-facilitators, and attended by a notetaker. Similar questions were asked to each group. These meetings were recorded and transcribed via Otter.AI ™ and resultant transcripts were cleaned by the notetaker for review (intelligent verbatim). Cleaned focus group transcripts were analyzed by three investigators (CC, LG, and ZE (author initials)) using MAXQDA 2022/2024 and reviewed independently by two additional investigators (LM and JP) for consistency, integrity, inter-

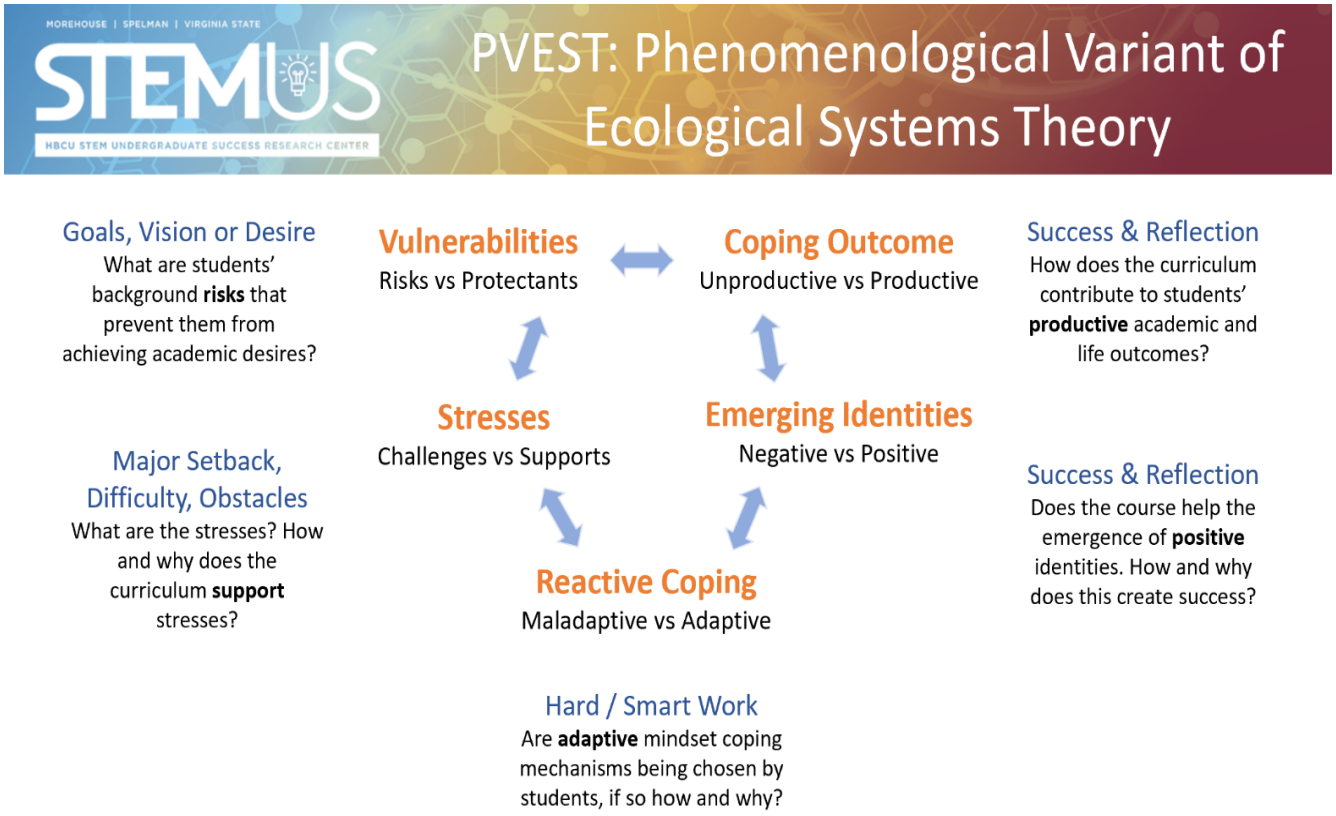
coder reliability, and accuracy (investigator triangulation). Open coding was utilized to capture the breadth of student responses and axial coding was used to specify a list of codes most relevant to student experiences. These axial codes and response frequencies are listed in Table 1. Student quotes which further exemplify these responses are highlighted throughout the Results as well.

Theoretical Framework: Phenomenological Variant of Ecological Systems Theory (PVEST)

The Phenomenological Variant of Ecological Systems Theory (PVEST) is a theoretical framework that examines student development from both individual and environmental perspectives (Figure 1) (Cunningham et al., 2023). It emphasizes the importance of understanding individuals' subjective experiences and perceptions of their environment in fostering motivation and positive developmental outcomes. Use of this framework has shown significant benefit when investigating diverse student populations where the influence of multiple social, cultural, and environmental factors is more likely to contribute to the general educational experience (Ozaki et al., 2020). PVEST is particularly useful for understanding an individual's risk and protective factors, their available sources of challenge and support, and the coping mechanisms they use. We utilize this framework to both characterize our unique student population as well as evaluate how the Scientific Literacy modules may have impacted development of their reactive coping mechanisms and emerging identities as scientists.

Figure 1

Phenomenological Variant of Ecological Systems Theory



Note: This figure is an adaptation of Dr. Margaret Beale Spencer's PVEST framework which was used to organize student focus group responses and analyze the effectiveness of the Scientific Literacy modules (Spencer et al., 1997).

RESULTS

Here we discuss the findings of our student focus groups (Table 1) and outcome analyses within the PVEST framework of (I) Vulnerabilities, (II) Stresses, (III) Reactive Coping, (IV) Emerging Identities, and (V) Coping Outcomes between both the FYS and FYSSL groups. Items I and II focus on our unique student population while items III, IV, and V relate to the evaluation of effectiveness of Scientific Literacy Modules (or FYS). Specifically, we assess the baseline characteristics of our student population (Both FYS and FYSSL) in terms of vulnerabilities and stresses, before then identifying how the Scientific Literacy modules have impacted the students' reactive coping, emerging identities, and coping outcomes (FYSSL)

Table 1

Student Focus Group Responses: Coded focus group responses for both FYS and FYSSL students reported as percent (%) frequency. Asterisks represent the top five most frequently mentioned subjects per group.

Major Code Subcode	Frequency (%) (FYS)	(FYSSL)	Major Code Subcode	Frequency (%) (FYS)	(FYSS)
Motivations To Enter Science			**Sense Of Belonging**		
Family	3.07	1.60	Positive Impact	0	1.83
Community	2.45	1.14	Negative Impact	2.45	0.23
Scientific/Career Interest	3.68	4.58	**Understanding of The Sciences**		
Diversity	3.07	0.23	Lacking Understanding	1.23	0
Perceptions Attending An HBCU			Gained Understanding	1.23	4.35
Past	2.45	1.14	Did Not Gain Understanding	2.45	0
Present	1.23	1.83	**Study Skills**		
Meeting Expectations	1.84	1.14	Gained	0.61	8.01*
Not Meeting Expectations	0	0.69	Needed	4.29*	2.75
Adjusting To College			**Study Groups**		
Experienced A Difficult Transition	1.84	0.69	Effective	1.23	7.09*
Did Not Experience A Difficult Transition	0	0	Ineffective	2.45	0.92
Things That Eased Transition	4.91*	2.29	Unused	2.45	0.23
Things That Made Transition Difficult	3.07	1.60	**Growth Mindset**		
Barriers To Learning			Display Growth Mindset	1.23	11.21*
Institutional	4.29*	4.35	Display Fixed Mindset	4.91*	0.23
Personal	4.29*	3.43	**Motivations To Stay In Science**		
None	0.61	0	Family	0.61	0
Were Overcome	1.23	3.66	Community	0	0.23
Were Not Overcome	6.13*	0.46	Institution	0	0
Instructor			Scientific/Career Interest	0.61	0.69
Beneficial	4.29	1.60	Self	0.61	0.46
Detrimental	7.98*	5.72*	**Career Focus**		
Departmental Support			Career Exposure	0.61	5.49
Lack Of Support	1.23	1.60	Career Development	0.61	2.52
Well Supported	4.29*	0.69	**Retention In The Major**		
Usefulness Of Courses			Thoughts of Staying In The Major	1.23	1.37
Useful (Sci-Lit)	0	6.18*	Thoughts of Leaving The Major	1.84	0.23
Not Useful (Sci-Lit)	0	0	Thoughts of Leaving The Institution	0	0.46
Useful (Non-Sci-Lit)	1.84	0.23	**Personal Development (Non-Academic)**	0	4.81
Not Useful (Non-Sci-Lit)	4.29*	0			

Characterization of The Student Population

Vulnerabilities (Risks and Protectants)

Vulnerabilities, from the PVEST framework, examines how both an individual's risk and protective factors contribute to development of their self-identity. It suggests that both risk contributors and protective factors must be examined simultaneously to understand ones "net-vulnerability." If risks outweigh protectants there is increased opportunity for perceived and actual stress. Though all humans are vulnerable to some degree, a subject's net vulnerability should be examined to help consider structures which either mitigate risk or create structural protective factors.

Risk. Clark Atlanta University, like most minority serving institutions, proudly serves demographics statistically associated with increased academic vulnerability. For example, of the 71 students who graduated with a Bachelor's in biological and biomedical sciences from CAU in 2021, 8% were men and 92% were women (Statistics, 2021). The majority of the bachelor's degree graduates for this major were also Black or African American (89%) with the remaining percentage made up of Non-Resident Aliens or Persons of Other Races (non- White, Asian, or Hispanic/ Latino). Though optional, of SAT scores submitted to CAU in 2022 the average 75th, 50th, and 25th percentile scores were 580, 490, and 450 for Critical Reading and 540, 480, and 430 for Math, both slightly lower than national averages. Additionally, 87% of undergraduate students at CAU received financial aid through grants or loans in 2022 which is slightly higher than national averages. Moreover, 32% of students enrolled at CAU in 2019 identified as first-generation college students, meaning that their parent(s) did not complete a 4-year college or university degree

Protectants. Though statistically "at risk," FYS and FYSSL focus group responses showed that students within the Department of Biological Sciences at CAU, regardless of Scientific Literacy exposure, are highly motivated to both enter and remain in the sciences. We identified several reoccurring motivating factors for these individuals including familial connections (i.e., parents in the medical field), community engagement (i.e., attendance to science fairs or being a part of a science club),

scientific/career interest (i.e., loving math and science or wanting to be a vet), and diversity (i.e., a desire to increase diversity in STEM). The participants most frequently commented on a prior interest in science. This interest either stemmed from participants remembering they always liked STEM, “I have always liked my Science and Math classes more than English and History,” to gaining an interest due to the pandemic, “So I was just really jumping around, and then I finally decided that I wanted to do infectious disease after COVID because it was really interesting.” Others chose to enter STEM because of family members. Most commonly it was entering into a profession because a mother or aunt was in the same field, “I’ve always wanted to follow my aunt’s footsteps and being a nurse.” Most unique to this population was the frequent mention of diversity in STEM as a motivating factor by either helping minority communities, “I’m going into something that’s in that realm like fertility and I want to focus more on Black women and I want to do that in a Black space,” or feeling inspired by diverse figures, “I first got an interest in STEM because I saw somebody who looked like me, a Black man on TV talking about something he really enjoyed and also talking about science.”

In addition to these motivations to enter STEM in general, participants from both FYS and FYSSL groups further displayed a sense of pride and belonging attending an HBCU often attributing their decision to the “home-like’ environment of these institutions with participants stating, “I chose an HBCU because I wanted to be around people that look like me” and “an HBCU will be real, like, home-ish.” Another participant described the environment as “just welcoming, it’s like a big family reunion.” Others attributed choosing an HBCU for more societal reasons, such as wanting to be around or help further Black success. One participant stated, “I chose Atlanta because almost everyone is Black and being successful. I want to see that and be in that environment” and another stated, “I just wanted to support like the cause, like getting my education from a historical Black college.” Subsets of participants also cited familial attendance to HBCU’s as a reason for their decision in institution. Together, although our student population maintains inherent academic risk, their strong motivations to enter and remain in STEM and unique institutional environment may help to combat their baseline vulnerabilities.

Stresses (Challenges and Supports)

Stresses, from the PVEST framework, examine the balance between challenges and supports with challenges being defined as major setbacks, difficulties, and obstacles that must be overcome to succeed in a given area while supports are those things in place which combat these obstacles to promote success.

Challenges. All participants (FYS and FYSSL) commonly discussed having a difficult transition from high school to college. When expanded upon, participants would commonly bring this difficulty up along with comparing their studying habits from high school and having to adapt these habits in college. For example, one participant stated "I never really had to study, or I never really just learned how to study. So, I had to teach myself how to study and then teach myself the stuff that I'm studying." When discussing what had caused a difficult transition into college, participants acknowledged various reasons. Two participants attributed this to being first generation college students, with one participant going further and adding that she could not rely on family for advice on experiences or troubles, "I'm also the first out of my immediate family to attend college. So, I can't really ask my mom about 'ma, how did how did you deal with this or with that?'" Participants commonly discussed the need to learn how to study as all participants expressed high school as easier than college. One participant stated, "I really didn't have to study prior to college [...] But now I have to study." Another participant further compared high school to college, "My stem courses humbled me so much, because I felt like a genius in high school. And then I got here, and I was just like, well, I don't know about that." Both participants expressed an ease in high school then subsequent change in either their actions or their perception of their own ability because of the difficulty of college.

Participants also expressed experiences with their instructor as an area of challenge. In discussing these experiences, dissatisfaction with instructors' teaching styles or expectations of prior knowledge were the most common culprits. For example, participants often pointed to the overuse of PowerPoint slides, "she goes through slides. It's like she's telling us what's on the board, we can already do that […] I need you to break it down," or having difficulty understanding the ways in which the instructor explains the content, "sometimes they explain it in a way that is just

not clicking for us because we're not there yet." In both scenarios, participants would discuss the need to teach themselves, with one participant stating, "you have to go the extra mile to figure out […] basically you have to be your own teacher."

Other challenges which participants from both groups reported were more personal in nature, mentioning the difficulty of working full-time and being in school, or their own mentality as a barrier. For example, when asked what barriers or challenges they experienced in their STEM courses, one participant noted "just me being in my own head […] one thing I definitely had to break was getting outside of my head and pushing myself to do better and expanding on what I already knew." In this excerpt, the participant acknowledged that a personal barrier they experienced was self-doubt which came as a "slap in the face" as they had an easier time in high school.

Supports. Although there were some negative experiences with instructors, there were also some beneficial experiences as supported by participants. When discussing beneficial experiences, one participant stated, "When I go to biology class, it makes me feel better because, I understand the information and I feel like me and my teacher kind of have a rapport, and I feel I'm glad that she made herself available." Another participant stated that their instructor would, "[help] explain more things like they ask me questions and see which part of the chapter I really need to focus on more." Additionally, participants shared their appreciation for instructors caring about their development as students and highlighted being given pamphlets for work opportunities after their instructor returned from a convention. Participants from both groups would also discuss how these types of positive interactions with their instructors improved their overall sense of belonging. Further, participants continued to shed light on how the university culture played a big part in their sense of belonging stating, "The campus culture really, like, brightens me up. When I walk in the cafe, the energy in the café is just so welcoming most of the time." They additionally mentioned feeling well supported by their department more often.

In easing the difficult transition to college, participants from both groups most

frequently discussed being supported by their friends or family. These friends and family had attended college themselves and would be reached out to for advice. For example, two participants expressed calling a family member who had graduated from college, one stating, “anything dealing with college, I call my godmother because my godmother graduated and she also has her degree in biology” the other stating, “academically, I’ll call my father and his mom because my dad has a degree from Morgan State and my grandmother has a PhD.”

Effectiveness of The Scientific Literacy Modules

Reactive Coping (Adaptive and Maladaptive)

Reactive coping, from the PVEST framework, looks at the ways in which students react to stressors to minimize stress/conflict. These responses can be adaptive such as confronting problems directly, seeking assistance from peers, or proactively applying strategies to support their academic success; or they can be maladaptive such as avoiding problems, not attending classes, dropping out, or behaviorally disengaging. When examining baseline of our student population’s experiences, students, regardless of Scientific Literacy exposure, experience the same vulnerabilities and stresses. However, the implemented Scientific Literacy modules are directly geared towards improving students coping responses to these stresses. As such, this section will highlight many comparative analyses between student experiences in the FYS course vs the FYSSL course to assess their effectiveness.

Adaptive. The largest difference in focus group responses comes in analyzing participants’ growth mindsets. A growth mindset is the idea that people can improve their abilities and develop their talents through effort and hard work, even if it takes time. People with a growth mindset are more likely to embrace challenges and are open to failure and see setbacks as opportunities to learn and grow (Dweck, 2006). They are more willing to practice deliberately and continuously learning new skills and they accept flaws and mistakes as opportunities for improvement. Participants who were exposed to the growth mindset module within the FYSSL course more frequently mentioned statements reflective of a growth mindset (11.21%) than their

FYS peers (1.23%). Some of these statements include participant responses like "I want to push myself. I want to challenge myself in STEM. STEM is all about challenging yourself and, you know, learning it's a learning process." Adoption of this mindset lead participants to take accountability for their academic journeys:

> I feel like it [understanding of their biology course] could grow more. It could grow a lot more if I was to put that much effort in, and not just effort for me from like studying more, taking more time and like trying to understand it in ways that are better for me and not just the way my teacher put it on the slide.

They even applied this philosophy to their study skills, "Okay, I'm going to try this one. And if it doesn't work, I'm going to try another one."

Despite both groups frequently mentioning barriers to learning and difficulties with their instructors, adoption of the growth mindset is a likely contributor to participants in the FYSSL course mentioning being able to overcome their barriers to learning more frequently than those in the FYS course (3.66% vs 1.23%). Some FYSSL participants directly mentioned how this mindset better prepared them to approach difficulties understanding their courses:

> And this just helped me going into my biology course because I was going through it. I was just like okay, there was another way around it. Like I could find a way to figure out what's going on and what the teacher was trying to teach me.

Participants in the FYSSL course also more frequently mentioned the study skills they gained during the semester (8.01%) than FYS participants (0.61) as well as their effective use of Study Groups (7.09% vs 1.23%). Some exemplifying statements include "the study skills part really helped a lot because it broke down ways […] where you can see which one was helpful for you." One participant mentioned how persistent they now are with studying difficult material stating:

> I go home and I redo the presentation so I can redo it in my own head. So, it makes sense to me. And then take my notes. And then sometimes I'll watch

> videos if I need help on further topics.

Participants also mentioned the importance of taking breaks to avoid cramming material:

> It's okay to take a step back when things get a little stressful. Do something that calms you, take a walk, I don't know, go get to hang out with your friends. It's always okay to step back and come back to something because it kind of brings you to a new mindset when you step away for a second. And then you see things in a new light.

Others mention their improved time management skills:

> I got a planner […] and that has helped me a lot plan my day, my classes, what I need to do. Even studying, I write that down […] And I take it day by day. I don't have to really force anything in my mind, "I gotta do this, I gotta do this, like, NO", I just do it day by day. And I just had to learn time management.

These skills even translated to changes in in-class behaviors including, "I would most definitely tell myself to pay attention, listen, and take in knowledge. Be there, in the class not just present. Interact with the class and ask questions, you know? Because you can't just learn by just sitting there."

Both FYS and FYSSL students were encouraged to use study groups, however the FYSSL course included specific modules on how to form effective study groups, which seemed to translate to their use as FYSSL participants reported positive experiences more frequently stating comments like:

> For me, it enhanced my learning because if one person didn't know it, or one person couldn't quite get how the professor had taught us, then the other person is able to break it down for everybody to understand it. And I felt like it was helpful.

Along with the benefits of shared learning, they also shared the benefits of peer-to-peer-teaching stating:

> You're also explaining things that you do know which helps you in your head. You know the knowledge so you're basically becoming the teacher. So, it helps you also grasp the information that you already knew better while also learning new stuff that you didn't know.

Another mentioned benefit of the study groups was the slower pace of learning as one participant shared, "So we're all learning, and it's just at a steady pace. At a steady, very slow and steady pace."

In all, students who participated in the FYSSL course more frequently discussed adaptive reactive coping strategies compared to those in the FYS course. This is evident when isolating the five most frequently discussed topics from each group as the FYS commonly mentioned: Instructor Detrimental (7.98 %), Displaying a Fixed Mindset (4.91%), Things That Eased College Transition (4.91%), and Study Skills Needed, Courses Not Useful, Well Supported by The Department, and Institutional and Personal Barriers to Learning all tied for 5th (4.29%). This contrasts the FYSSL group who most frequently mentioned Displaying a Growth Mindset (11.21%), Study Skills Gained (8.01%), Study Groups Effective (7.09%), Usefulness of Scientific Literacy (6.18%), and Instructor Detrimental (5.72%). These differences and interpretation of responses show that though FYS and FYSSL students face similar stresses, the FYSSL group interprets their challenges differently and show more interest in solution-based approaches and adaptive coping mechanisms than their FYS counterparts.

Maladaptive. In general, students from the FYS course more frequently displayed maladaptive coping mechanisms than their FYSSL counterparts. This is largely evident through the FYS participants frequent mention of the lack of utility of their courses (4.29%) whereas participants in the FYSSL course had no mention of any lack of utility. Participants in the FYS also more frequently mentioned statements reflecting a Fixed Mindset (4.91%) than their counterparts (0.23%). A fixed mindset is the belief that intelligence, talent, and other qualities are innate and unchangeable (Dweck, 2006). People with a fixed mindset may think that if they are not good at something, they will never be good at it. They may also believe that mistakes are a sign of personal failure and be unwilling to take risks or challenges for fear of

being seen as inadequate. This mindset is likely responsible for the discrepancies in gained study skills and use of study groups between course participants. Participants from the FYS course commonly mentioned understanding the importance of study skills, but either did not know how to obtain them, did not believe they need to obtain them, or did not believe they had the ability to obtain them. When asked about the development of study skills, some responses from FYS participants included, "I feel like the amount that I study is the same. Realistically. I don't know how to get better at studying" and "Surprisingly, that's why I haven't bettered my studying skills, because it's working. Like whatever I'm doing it's working. Procrastinating is always getting it done, so I keep on procrastinating." Similar sentiments were shared when asked about the use of study groups, i.e.:

> I don't do any sort of groups. And I don't want to say it's because I don't know how to study but it's more so because […] studying for me personally is pointless only because every time I do study, when I get the test or when I get the assignment, my mind goes blank, so I feel like it's wasting my time. I mean, I know it's helping me, but it just feels like it's wasting my time.

These types of maladaptive coping responses led to an increase in mention of a Negative Sense of Belonging (2.45% vs 0.23%) and Thoughts of Leaving the Major (1.84% vs 0.23%) that were not as prevalent in participants of the FYSSL course.

Emerging Identities

Emerging identities in this context is comparable to STEM-oriented self-construal, which has proven critical to development of early-stage scientists (i.e., first-year biology majors) (McLean et al., 2022; Perez et al., 2014). It asks the question of how self-perceived identities of the student change throughout exposure to course materials and their overall academic environment. Examples of positive emerging identities include showing confidence pursuing a STEM career/graduate career and self-identifying as a scientist or STEM professional. In this section we focus on how the FYSSL course helped students develop positive emerging identities more so than the traditional FYS.

The area in which positive emerging identities is most prevalent amongst FYSSL

participants is in the career focused nature of their responses. Participants who completed the FYSSL course much more frequently mentioned both Career Exposure (the gained knowledge of diverse STEM careers) (5.49% vs 0.61%), and Career Development (activities which enhance their competitiveness as STEM professionals) (2.52% vs 0.61%) compared to those in the FYS course. This is in large part due to exposure to Scientific Literacy Modules 9 and 10, Careers in STEM and Research Experience for Undergraduates, which heavily emphasized these topics. In the realm of career exposure, participants from the FYSSL course showed appreciation for the knowledge of additional career opportunities they could pursue with their degrees stating, "it shows you a list of jobs and opportunity that you might be interested in. So, there's always a way to use your STEM degree" and:

> This course actually kind of helped me on what I want to do in the future. Honestly, because I didn't realize what you can do with a biology degree and taking this class, we had to research different internships or different career fields in the STEM field overall, so I definitely think it helped like me finding my way.

One participant even cited the modules as a primary factor in choosing a compatible career path:

> I realized that I'll probably be doing human clinical trials or something like that within my future. That's something that I want to do because I'm hands on and I like to do research, so learning about the research PowerPoint that we went over it was definitely something that made me kind of like "okay, maybe this is something that like I should probably take interest in in my near future."

In addition to an increased awareness of different career paths in STEM, FYSSL participants were further set apart by their mention of career development opportunities needed to progress them to and through their careers (2.52% vs 0.61%). This included an increased desire for internships and career fairs as well as an emphasis on how improving grades can help them achieve career goals. One participant mentioned, "it [FYSSL] helps find different opportunities for stuff like internships,

and we talked about it the importance of actually taking an internship, and that what our grades should look like to get into internships. It was encouraged to have good grades." Students also took this beyond classroom learnings and frequently mentioned plans of participating in summer research experiences as part of their career development. One participant stated:

> Another thing that I hope to accomplish while taking this course is getting an internship like this upcoming summer because he (the instructor) had laid so much out on the table about the internships and work opportunities that we have. So I feel like I probably will be, or will reach out to a lot of opportunities after taking this course because I've learned so much and it has helped me in the real world and in my academics as well.

This exposure to career development opportunities seemed especially important to this student population as it appeared most students had not gone through a summer enrichment program prior to college, which is true of most minority student populations, i.e., "I could be open to try new things just as such as internships since I've never did one before and I know that I want to be a veterinarian."

The increased career focus of FYSSL student responses was also coupled with an increased mention of positive impacts on their sense of belonging (1.83% vs. 0%). One participant shared that, "I feel better prepared about my academic future at Clark Atlanta, and then a little bit more secured and picking my career path after college" upon completing the FYSSL course. Together, these show that students are building emerging identities as not only college students, but early career professionals, and individuals who belong in STEM. In addition, participants from the FYSSL course frequently mentioned their personal non-academic growth (4.81% vs. 0%) showing that these lessons and emerging identities extend beyond the classroom. One quote which exemplifies this most comes from a participant response to finding benefit in their courses, responding:

> Yes, but not just academic, even running a business, because I do nails and stuff. You will have to have a certain mindset you have to want to keep going. You will have to, to reach the goal where you want to be […] Because

> it's been days where I don't want to do it anymore, or where I don't want to really push myself, but you know, you have to think and you have to take in what you learn and what you know, and you have to just let it be your drive and let it push you. So, I feel like it helped me on my day to day.

This again highlights the benefits of introducing the growth mindset and how it can also have profound effects on emerging identities even outside of STEM.

Coping Outcomes

Coping Outcomes within the PVEST framework evaluates how changes in reactive coping mechanisms manifest into real world changes in outcomes. In this context, we evaluate how the positive coping mechanisms gained by students in the FYSSL course changed their productive academic outcomes, specifically, their understanding of the sciences and their attitudes towards retention in the biology major.

When participants discussed perceptions of how well they now understand science, students who completed the FYSSL course exclusively provided responses reflective of gaining an understanding (4.35% vs. 1.23%) as opposed to lacking and/or not gaining an understanding (both 0%). Participants often reflected on their appreciation for this new understanding such as sharing:

> Me personally, I feel like I've learned a lot, but I've utilized every class that has something to do with biology like my lab, my seminars, what I'm learning in my lecture, I utilize all of that. And that's how I'm able to learn.

This increased understanding of the sciences even showed when participants described what exactly scientific literacy means to them as one participant stated, "That's what scientific literacy means to me; actually knowing what you have to do to even apply the tools that you learned in your electives, classes, and in your lab, and how to go about it." Another also shared that:

> Science is more than just knowing the words. It's like, okay, can you take this and describe it in a way that makes sense to you? Or can you take this and describe it in a different way? Like, do you know something other than

> the book definition?

These responses demonstrate students' progression to higher levels of learning through Blooms Taxonomy (a central theme introduced within the FYSSL modules) which places more emphasis on evaluation, analysis, and application of science over simply understanding and remembering.

Participants from the FYS also shared sentiment that they gained and understanding of the sciences; however, this group was more evenly divided in their responses between initially lacking an understanding (1.23%), gaining an understanding (1.23%), and not gaining an understanding (2.45%). Those participants who felt like they did not gain an understanding for science also shared worries about how that would affect the remainder of their academic journeys, i.e.:

> I just feel like we're just now getting started, like we're not really into our major. We just have like the general classroom now. So, we don't really have a perspective on biology, how's our experiences going to affect us later on?

Another participant shared, "I feel like next year […] hopefully, it's more like into biology because right now just feels like we're just on the surface." This shows students in both cohorts are forward thinking and focused on their academic journey, but also highlights a need to help connect scientific concepts for students in the FYS to capitalize on their growing hinger for knowledge.

By frequency, participants in both the FYS and FYSSL courses shared similar responses as to Thoughts of Staying in the Major (1.23% vs. 1.37%). However, participants in the FYSSL course mentioned Thoughts of Leaving the Major far less frequently than those in the traditional FYS (0.23% v.s 1.84%). Participants in the FYSSL also tended to mention concepts from the Scientific Literacy modules when explaining why they wanted to stay in their respective majors, most notably the growth mindset, as one participant recalled:

> It's a reminder of why I still want to go through the career path I want to go to. And it reminds me of how I still want to help people even though I'm struggling right now. I can still make a change and be better.

Participants from the FYSSL course shared a wide array of career affirmation with some sharing more concrete responses such as, “I really want to be a veterinarian. This is what I’m sticking to I don’t want to be in between majors or in between career paths. I want to have this mindset,” and others sharing more general sentiments including “I see myself finishing my undergrad, I guess and preparing to go to my DPT program, trying to get into a DPT program” and “regardless of how I’m doing now I can always be better and make a change and help other people do better.” To either degree, these affirmations of staying in the major and continuing to their career paths only enhance their emerging identities and coping outcomes and are likely to increase their overall STEM retention.

Discussion

As one student very eloquently stated:

> Scientific Literacy is really just taking what you know and also learning more during your process of going to school for further education. And being able to apply that during your education process, during your career path, and really understanding what you’re wanting to do with your life in science.

This definition may not be found in a textbook, but it is a great reminder that any class can be best summarized by what the students ultimately take out of it. Through this report we highlighted real-world student responses and attitudes towards implementation of a scientific literacy curriculum into their traditional first-year experience course. Though response frequencies were the basis of these comparisons, future reports can further explore the level of details. Through the lens of the PVEST theoretical framework we were able to show how this integrated course mitigated our student populations baseline academic vulnerabilities and risk by providing them with positive coping strategies to better equip throughout their journeys. Students who participated in the FYSSL course more frequently mentioned overcoming barriers to learning, gaining an understanding of science, and displaying a career focus. FYSSL participants also reflected on the study skills they gained and their effective use of study groups more frequently than their FYS counterparts. Furthermore, these participants displayed a growth mindset throughout their responses to their

respective academic endeavors.

In all, these student experiences demonstrate the effectiveness of the Scientific Literacy modules at improving self-perceived outcomes and student attitudes towards retention in STEM. They also show the effectiveness of implementing these modules in a traditional first-year experience. We believe these findings are applicable to a broad student audience but maintain that student populations with increased baseline vulnerabilities such as those at minority serving institutions have the most potential benefit.

Limitations

Students who participated in the Fall 2023 FYS and FYSSL are first-year biology majors slated to graduate in 2027. As such, longitudinal retention and graduation will be included in subsequent publications as this report highlights self-perceived intentions of retention and known predictors of academic success. Due to small attendance in FYS focus groups compared to FYSS, comparative analyses are limited, and statistical analyses of significance are not included, reported, or assumed in this report. Differences in focus group size also likely impacted richness of focus group discussion, limiting interpretations. However there remain opportunities for robust qualitative and quantitative assessments following future iterations of the course, including a detailed comparison of FYS and FYSSL groups. Lastly, though focus group questions were standardized between groups, we acknowledge the influence that Scientific Literacy modules may have on FYSSL responses and believe this only highlights the course's effectiveness and students chosen retention of course materials.

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Author Contributions

CC, AN, BC, LM, and JP conceived and executed the research project. CC, LG, and ZE wrote and edited the manuscript with input from all authors. JP serves as the senior and corresponding author. All authors reviewed and approved the final version of the manuscript.

Data Sharing

All Scientific Literacy course materials can be found at Scientificliteracycenter.org and any data used in creation of this report can be made available upon reasonable request to the STEM.US Scientific Literacy Center at Morehouse College with approval from the Department of Biological Sciences at Clark Atlanta University.

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