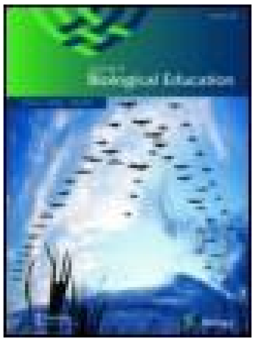

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Preliminary outcomes from a learning community to increase biology course knowledge

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ABSTRACT

The purpose of this study was to evaluate the preliminary outcomes of a learning community intervention (LC), which was based on the performance pyramid theoretical model of student supports. The LC integrated college algebra into biology course work. We used a quasi-experimental design to compare LC students to separate General Biology I and College Algebra course control groups on respective measures of biology and algebra course knowledge, and an assessment of perceived performance pyramid supports. Participants included 198 students (LC, n = 22; biology control, n = 52; mathematics control, n = 124) at a Historically Black University in the Southern United States. An analysis of covariance (ANCOVA) indicated that the LC students had significantly greater performance from pre- to post-test on a measure of biology course knowledge (Cohen's d = 0.76) compared to the biology control group. An ANCOVA indicated that the LC and mathematics control students performed similarly on a measure of algebra course knowledge. Group differences from a multivariate analysis of covariance on perceived performance pyramid supports were mostly statistically non-significant. Overall, the LC increased biology course performance. Implications for improving biology course performance and better assessment of students' perceptions of support for academic success are discussed.

KEYWORDS
College biology; college mathematics; learning community; student support; post-secondary STEM education; performance pyramid

African-American students comprise 12% of the undergraduate enrolment for four-year higher education institutions in the United States, but 10-year trends indicate that they comprise 7% of the bachelor's degrees conferred in biology (National Science Foundation, National Center for Science and Engineering Statistics [NSF], 2019). Further, approximately 14% of college entering African-American students intend to major in biology, but only 4% graduate with a bachelor's degree in biology. This is the greatest discrepancy between intent and degree completion when all race/ethnicity groups are compared (NSF, 2019). This means that African-American students have a greater attrition rates than all other minority student in the United States, as well as college students in general. Nonetheless, there is evidence that African-American students' probability of degree completion increased by three to five times when mathematics preparation barriers and socioeconomic barriers are removed (Ma and Liu 2017).

Conceptual models exist for providing supports to underrepresented minorities (URM) entering science, technology, engineering, and mathematics (STEM) fields. Models have overlapping emphases on learning history, investment in academic tasks through dedicated time and personal enjoyment, and clear standards for content mastery with ongoing faculty and peer supports for academic success (Astin 1984; Tinto 2010). This fits with general recommendations that STEM

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support programmes address academic and social aspects of URM development in their degree programmes (Alkhasawneh and Hargraves 2014). This entails integrating access to campus resources to address learning needs, as well as regular faculty and peer interactions across classroom and non-classroom settings (Palmer, Davis, and Thompson 2010; Tinto 2010).

Models to promote specifically STEM success for African-American students have emphasised cultivating environmental support (Arroyo and Gasman 2014). For instance, students are believed to have greater success if there are connections to peers and faculty beyond the classrooms. Further, access to more academically prepared peers is believed to facilitate opportunities for equitable academic achievement. The eventual success of these students relies on being in a setting where they can see other African-Americans succeed, form an identity around academic success, and see value in their academic pursuits (Arroyo and Gasman 2014). Others have implemented peer led teams to deliver faculty developed modules related to course content, as well as facilitate a bridging programme for small groups of first year students. Further, faculty acted to provide feedback and mentoring outside of classroom settings for projects and professional development (Gasman et al. 2017). In this manner, students received peer support to access the curriculum and faculty support to help connect their programmes to valuable pursuits.

Learning communities

Learning communities (LCs) align with recommended practices for African-American STEM students (Freeman, Alston, and Winborne 2008). LCs are groups of students, who are connected purposefully as a cohort through enrolment in common courses and structured learning experiences (Han, Dean, and Okoroji 2018). The purpose of LCs is to improve college students' academic engagement and course performance by using study groups and fostering contact with peers and faculty members. Additionally, LCs foster integration of college students by socialising them to the culture of the institution (Xu et al. 2018). LCs are commonly developed around interdisciplinary curriculum needs, where students are brought together to complete specific corresponding courses together (Love 2012). These LCs are preferable due to ease of linking specific course content, making few changes to the courses, and needing few resources to develop them (Baker and Pomerantz 2000). LCs that combine course work increase student satisfaction with their programmes and performance in course work (Dagley et al. 2016; Lee, Khalil, and Boykin 2019; Salomon et al. 2015). Positive outcomes have been demonstrated with biology centred LCs for course grades, retention, and sense of belongingness (Xu et al. 2018).

Nonetheless, there is a wide range of practices employed within LCs to provide services to students, which include cohorts, peer led teams, and mentoring. However, these models have been based on long standing conceptual frameworks (Arroyo and Gasman 2014; Gasman et al. 2017) or predictive models (Alkhasawneh and Hargraves 2014), rather than theoretically driven models. Theory-based models can be used to develop environmental and instructional supports to address multiple causes of URM STEM failure. That is, an integrated approach that includes wider supports might provide improved outcomes for African-American STEM students.

Performance pyramid

One model for assessing and addressing a variety of elements that promote student success is the performance pyramid (Wedman and Diggs 2001). The performance pyramid is a theory-based model with elements that are believed to promote success for STEM students. Performance is defined as valued actions and accomplishments of individuals (Watkins and Wedman 2003). The purpose of the performance pyramid is to develop methods for comprehensive assessments of student needs in order to produce changes in the surroundings and instruction to increase student success (Watkins, West Meiers, and Visser 2012). The performance pyramid has six interrelated elements: (a) Knowledge and Skills; (b) Performance Capability; (c) Rewards, Recognition and

Incentives; (d) Tools, Environments and Processes; (e) Expectations and Feedback, and (f) Motivation, Values, and Self-efficacy (Wedman 2010; Wedman and Diggs 2001).

Performance pyramid elements

The Expectations and Feedback area is related to explicit information regarding courses or degree requirements, and how to successfully complete these requirements (Park and Ertmer 2008; Watkins, West Meiers, and Visser 2012; Wedman and Diggs 2001). In essence, this element can be thought of as receiving procedural feedback to complete tasks. Tools, Environment, and Processes refer to access to physical resources, areas or opportunities to engage in degree related tasks, and organisational support (Park and Ertmer 2008). Respectively, examples of these are technology or study materials, quiet or group study locations, and availability of faculty and support staff (Watkins, West Meiers, and Visser 2012; Wedman and Diggs 2001). The Rewards, Recognition, and Incentives element is related to receiving acknowledgements and incentives for adequate academic performance (Park and Ertmer 2008; Watkins, West Meiers, and Visser 2012; Wedman and Diggs 2001). These incentives could be in the form of grades or tangible rewards, and should be motivating to the individual (Schaffer and Richardson 2004).

Motivation, Values, and Self-efficacy represent the extent to which individuals perform because they see benefits related to the academic task and desire to continue with related tasks (e.g., relating courses to career and goal setting; Park and Ertmer 2008; Watkins, West Meiers, and Visser 2012). Performance Capacity includes individuals' environmental, interpersonal, and intrapersonal resources to complete necessary work (Park and Ertmer 2008; Schaffer and Richardson 2004; Wedman 2010). These could include being free of conflicting responsibilities, having time to complete individual and group projects, and having the ability to understand how to complete assignments adequately. Knowledge and Skills refer to adequate academic preparation prior to and during courses and degree programmes (Allen and Saparova 2015; Park and Ertmer 2008; Watkins, West Meiers, and Visser 2012). Previous as well as continued acquisition of knowledge and skills related to classes or a' major' are reflected in this domain.

Student perceptions of the performance pyramid

We incorporated the performance pyramid into an LC for the integration of mathematics into an introductory biology course content. The LC was created to address the difficulties that undergraduate biology students had related to applying mathematical concepts to the biology course work at a historically Black University (HBCU; see Li and Gross 2019). Each element of the performance pyramid was integrated into the LC components, which included LC learning activities and adjunct activities, such as meetings for iterative LC programme development.

It was assumed that if performance pyramid elements were purposefully integrated into the LC, then students in the LC would perceive these supports. Nonetheless, the performance pyramid elements were applied based on the perspectives of the LC programme developers. What needs to be clarified is if the performance pyramid supports are salient to the LC participants. There have been needs assessments developed using the performance pyramid framework (e.g., Lei et al. 2004; Schaffer and Richardson 2004), as well as psychometric studies of student perception of performance pyramid elements (Gross, Li, and Lockwood 2019; Hardy and Aruguete 2014). However, there is limited evidence of how these elements are perceived by students when receiving interventions based on the performance pyramid. Specifically, it is unclear if students receiving performance pyramid interventions experience greater levels of these supports when compared to students receiving instruction as usual.

Purpose

The purpose of this study is to present the primary outcomes from the first cohort to receive this LC intervention. We wanted to determine if the LC improved student knowledge and perceptions of being supported. Students in LCs were compared to separate biology course and college algebra course control groups. Each control group took the same respective biology or algebra course as the LC group, but did not receive further instructional support than what was offered to all students at the HBCU. The research questions we addressed were:

(1) Do students who participate in the LC have greater biology knowledge than students who take the same introductory biology course and receive instruction as usual (IAU)?
(2) Do students who participate in the LC have greater algebra knowledge than students who take the same college algebra course and receive IAU?
(3) Do students who participate in the LC have greater rating on measures of support related to the performance pyramid than students who receive IAU?

Method

Participants

Study participants included 198 students enrolled at an HBCU in the Southern United States during fall and spring semesters for one academic year. Students were recruited through convenience sampling and were identified as in one of three study groups: (a) LC, who received the LC intervention; (b) Biology Control (BC), who attended the same biology course as the LC group; and (c) Maths Control (MC), who attended the same college biology course as the LC group. (Table 1 contains the demographic information for each group). The LC group was made up of mostly participants who identified as female, which was statistically significantly different than the MC group, but not the BC group, $\chi^2(2, N = 190) = 9.29$, $p = .010$, Cramer's V = .21. Further, the LC and BC groups had a higher proportion of STEM majors, $\chi^2(2, N = 198) = 40.31$, $p < .001$., Cramer's V = .45.

Required courses

Biology course

There were two sections of the biology course available, each taught by a different instructor. The first instructor has a Master's degree in Biology and had 40 years of college teaching experience. The second instructor has a Ph.D. in Biology and 8 years of teaching experience. Both sections covered the same content and completed the same assignments, quizzes, and exams. The topics covered in the General Biology course included: (a) the scientific process and tools for biology; (b)

Table 1. Demographic information across study comparison groups.

	LC	Biology Control	Maths Control
	M(*SD*)	*M*(*SD*)	*M*(*SD*)
Age in Years	17.91(0.53)	18.24(0.79)	18.44(1.13)
Year in College	1(0)	1.24(0.47)	1.23(0.62)
	N(%)	*N*(%)	*N*(%)
Gender			
Female	21(95%)	38(73%)	75(61%)
Male	1(5%)	13(25%)	42(34%)
Unknown	0(0%)	1(2%)	7(6%)
Race/Ethnicity			
Asian/Pacific Islander	0(0%)	0(0%)	2(2%)
Black/African American	21(95%)	50(96%)	111(90%)
Native Hawaiian	0(0%)	0(0%)	1(>1%)
Other/Unknown	1(5%)	2(4%)	10(8%)
Primary Language English	21(95%)	50(96%)	108(87%)
STEM Major	22(100%)	49(94%)	63(51%)
Total	22	52	124

measurements in biology; (c) acids, bases, and solutions; (d) biologically important molecules; (e) cells; (f) diffusion and osmosis; (g) enzymes; and (h) mitosis and meiosis.

College algebra course

There were three sections of the college algebra course available, where one instructor taught two sections and another instructor taught one section. The first instructor has a Ph.D. in Applied Mathematics and 15 years of college teaching experience. The second instructor has a Master's in Mathematics and 15 years of teaching experience. Both sections covered the same content and completed the same assignments, quizzes, and exams. The topics covered in the College Algebra course included: (a) advanced study of algebraic equations and inequalities; (b) complex numbers, functions and their graphs; (c) polynomial and rational functions, and their graphs; and (d) exponential and logarithmic equations, functions, and their graphs.

Independent variable

Learning Communities (LC)

Students in LCs received the LC intervention, as well as concurrently attending one section of the introductory biology course and college algebra course. These students took the same biology and college algebra course sections. However, they were assigned to one of four different LC groups, each with a different peer partnership leader (PPL). The PPLs were senior students at the university, who facilitated the LC activities. The LCs met for 14-weeks during the fall semester, for one hour per week outside of the regular class time. Spring semester LCs were not offered because the introductory biology course was not offered in the spring semester.

The LC weekly activities included completing half of a two-week co-curricular project that related to concurrent biology and algebra course content. The projects included: (a) Calculating BMI value; (b) Metric System and Unit Conversion; (c) Dilutions; (d) Diffusion and Osmosis; (e) Enzymes; (f) Solutions and pH Value; and (g) Mitosis. In addition to the co-curricular projects, weekly activities reflecting different aspects of the performance pyramid were used (Table 2). These were separated by the first and second week of each co-curricular project. The first week included using a log to monitor performance on course key assessments (e.g., tests and homework), engaging in team building exercises, reviewing places to study, reviewing biology and mathematics key

Table 2. Learning community activities and corresponding performance pyramid elements.

Procedure	Performance Pyramid Element
Project Week 1	
Check use of Course Performance Logs	Performance Capability/ Expectations and Feedback
Team building exercise	Performance Capability
Review places to study/complete work	Performance Capability
Review Biology/Mathematics Key Concepts	Knowledge and Skills
Connect Biology/Mathematics Key Concepts	Knowledge and Skills
Expectations/Syllabus Review & Goal setting for up-coming course requirements	Expectations and Feedback
Project Week 2	
Check use of Course Performance Logs	Performance Capability/ Expectations and Feedback
Applied Biology Group Project	Knowledge and Skills
Academic/Social/Cognitive Skill Topic	Knowledge and Skills
Expectations/Syllabus Review & Goal setting for up-coming course requirements	Expectations and Feedback
Check-in questionnaire	Motivation, Values and Self-efficacy
Adjunct Activities	
Weekly Project Evaluation	Rewards, Recognition and Incentives
Attendance Tracking	Rewards, Recognition and Incentives
Informational Resources	Tools, Environment and Processes
Dubois 350 – Meeting Room	Tools, Environment and Processes
PPL leader-Faculty meeting	Tools, Environment and Processes

concepts, connecting biology and mathematics key concepts, syllabus reviews with goal setting for up-coming course work. The second week included using a log to monitor performance on course key assessments, completing the co-curricular project as a group, developing academic/social skills, syllabus reviews with goal setting for up-coming course work, and completing a check-in questionnaire regarding perceived efficacy and motivation.

Regarding specific performance pyramid elements, *knowledge and skills* was addressed by comparing key concepts across introductory biology and college algebra courses and completing co-curricular projects, with corresponding biology and mathematical content being developed. *Performance Capacity* was reflected in having students review and record upcoming and completed assignments, including team-building exercises, and identifying places to work on course materials. *Tools, Environments and Processes* was addressed by supplying study guides and other materials related to intersecting biology and mathematics and assuring that the physical locations for LC activities were adequately comfortable and equipped for meetings. Further, peer leaders facilitated the LC co-curricular projects to supplement in-class instruction, as well as having monthly meetings with programme faculty to address student support needs.

Rewards, Recognition, and Incentives was incorporated by having competitions for the best completed unit exercise, earning extra credit for attending LC meetings, participating in group discussions, and timely submission of unit projects. *Expectations and Feedback* was addressed through multiple activities. The LC leaders completed syllabi reviews independently. The leaders would then review syllabi with the LC students on a weekly basis, which included plans for completing assignments and setting goals for up-coming course work scores. LC students kept a log of their grade from assignments, quizzes, and exams. LC students compared goal and actual grades, where LC leaders offered individualised feedback for improved academic task performance. The activity related to *Motivation, Values, and Self-efficacy* entailed alternate weekly check-ins, where the students related their interests and skills in biology and maths, as well as identifying a STEM role model and connections between biology and maths.

There were other adjunct activities that included weekly co-curricular project evaluations, attendance tracking, informational resources, dedicated meeting rooms, and PPL meeting with instructors and the project primary investigators (PIs). Further details of the LC procedures related to the performance pyramid model can be found in Li and Gross (2019).

Biology Control (BC)

Students in the BC group attended the same introduction to biology course that the LC student attended in the fall. However, these students received IAU, as well as any supports typically offered to students at the University. The University offered services through the Leadership Enrichment and Academic Development programme (LEAD). Students can request free tutoring, academic skills enrichment, and academic counselling services through LEAD programme. BC data was only collected in the fall semester because the course was not offered in the spring semester.

Maths Control (MC)

Students in the MC group attended the same college algebra course that the LC students attended in the fall or the same course with the same instructors in the spring semester. However, these students received IAU, as well as any supports typically offered to students at the University. The University offered a Maths Lab, which offered free tutoring to students registered in all level mathematics courses. The Maths Lab runs from 7:00 p.m. to 9:00 p.m. from Sunday to Thursday, starting three weeks after the classes start. In addition, the university also offered multiple services through LEAD programme.

Dependent variables

Biology quiz

A biology quiz was developed based on the General Biology I course content and related applied mathematical concepts. The quiz had 20 multiple-choice items and 5 points were given for each correct answer and 0 points for each incorrect answer, with a maximum of 100 points. Five (5) points were given for each item to keep the arithmetic for the quiz scores straightforward and easily interpretable for the students. Items covered content from converting units of measurement to applying concepts to simulated laboratory data. Higher scores indicated greater knowledge of course related biology content. Cronbach's alpha at pre-test was .41, but was .74 at post-test. It is likely that the pre-test low Cronbach's alpha was due to limited biology knowledge; whereas, the post-test coefficient could be due to increased knowledge of connected, but distinct concepts.

Maths quiz

An algebra quiz was developed based on the College Algebra course content and concepts. The quiz had 20 multiple-choice items and 5 points were given for each correct answer and 0 points for each incorrect answer, with a maximum of 100 points. Similar to the biology quiz, each item was given five points to keep the arithmetic for the quiz scores straightforward and easily interpretable for the students. Items covered content, such as advanced algebraic equations and functions, as well as exponential and logarithmic functions. Higher scores indicated greater knowledge of course related mathematical content. Cronbach's alpha at pre-test was .69, but was .75 at post-test. We estimate that the changes in the coefficient were due to similar reasons as the biology quiz.

Student Support Needs Scale-Augmented (SSNS-A)

The SSNS-A (Gross, Li, and Lockwood 2019) was developed as a student-report measure to assess different aspects of student support needs related to the performance pyramid theoretical model. There are seven subscales with each subscale having five items, and the items are rated from 1 (*Strongly disagree*) to 6 (*Strongly agree*). Higher item mean scores indicate greater presence of each performance pyramid element. There are seven SSNS-A subscales: (a) Knowledge, (b) Performance, (c) Motivation, (d) Tools/Environment, (e) Feedback-Procedural Expectations (Feedback-PE), (f) Feedback-Rewards, Recognition, and Incentives (Feedback-RRI), and (g) Self-efficacy. A pilot study of the scales found adequate internal consistency for the subscales (McDonald's omega [ω] = .67 to .94, with six scales $\omega > .8$; Gross, Li, and Lockwood 2019).

The Knowledge subscale measured academic preparation for prerequisite knowledge needed to succeed in major-related courses (Cronbach's $\alpha_{pretest}$ = .73, $\alpha_{post\text{-}test}$ = .73). The Performance subscale had items that assessed completing theassignment individually and in groups, as well as passing exams ($\alpha_{pretest}$ = .54, $\alpha_{post\text{-}test}$ = .53). Students' interest and hopefulness related to their major was measured by the Motivation subscale ($\alpha_{pretest}$ = .82, $\alpha_{post\text{-}test}$ = .81). The Tool/Environment subscale represents institutional resources dedicated to academic work completion ($\alpha_{pretest}$ = .82, $\alpha_{post\text{-}test}$ = .80). The Feedback-PE subscale represents instructor feedback to students regarding expectations of students and student performance ($\alpha_{pretest}$ = .83, $\alpha_{post\text{-}test}$ = .84). The Feedback-RRI subscale items involve identifying that instructors provide recognition, rewards, and incentives for performance ($\alpha_{pretest}$ = .88, $\alpha_{post\text{-}test}$ = .86). The Self-efficacy subscale measures perceived competency at course tasks ($\alpha_{pretest}$= .93, $\alpha_{post\text{-}test}$= .93).

Procedures

PPL recruitment and training

A flyer and an application form were distributed to all students at the University through the student email listserv. Application forms were also available for pick-up outside the PI's and a Co-PI's offices. After a pool of applications were gathered, applicants were interviewed by the PI and a Co-PI. The criteria for consideration included (a) an A or B for both College Algebra (or exempt from College Algebra) and General Biology I; (b) 3.00 or above cumulative GPA; and (c) a STEM major. All of the PPLs were required to attend mandatory training, which consisted of two days in the summer and one day during the academic year. During this training, the PPLs were given an introduction to the project, the roles and responsibilities of PPL position, and the content training in both College Algebra and General Biology. In addition, the PPL leaders were also trained on how to record data for the surveys, check-in questionnaires, attendance records, and knowledge tests.

Participant recruitment and consent

On the first day of class for the semester in the General Biology I and College Algebra sections, a participant consent form was distributed to students along with the pre-test surveys and knowledge quizzes. The project team then gave a presentation on the purpose of the project. They also reviewed the security and confidentiality of their personal information, and allowed for students to ask questions regarding the project or data collection. Students were reminded that they had the option not to participate in the study, and to withdraw at any time during the process, and that participation will not affect their course grades. All recruitment and data collection procedures were approved by Fisk University and Western Kentucky University (IRB 18–235) Institutional Review Boards.

Pre-test collection

Students in the LC group were given a pre-test survey and knowledge quizzes for both College Algebra and General Biology on the first day of the class. Students in the BC group were given a pre-test survey and knowledge quiz for General Biology on the first day of the class. Students in the MC group were given a pre-test survey and knowledge quiz for College Algebra on the first day of the class. Students had 20 minutes to complete the survey and 45 minutes to complete the knowledge tests.

LC Meetings

During bi-weekly meetings with PPLs, the PI and a Co-PI discussed the challenges and barriers that the PPLs encountered during their LC sessions. The group would identify and develop potential solutions, and finally agree on a specific plan to handle the challenges and barriers. Additionally, the PPLs also shared approaches that worked well when they led the group discussions. Finally, PPLs shared a successful story that took place while running the sessions.

Post-test collection

Students in the LC group were given a pre-test survey and knowledge quizzes for both College Algebra and General Biology on the last day of the respective class. Students in the BC group were given a pre-test survey and knowledge quiz for General Biology on the last day of the class. Students in the MC group were given a pre-test survey and knowledge quiz for College Algebra on the last day of the class. Students had 20 minutes to complete the survey and 45 minutes to complete the knowledge tests.

Treatment fidelity

Treatment fidelity was collected through an observational checklist developed for each LC session. Each of the five PPLs was observed for adherence to the session steps for the first and second week of two projects. The observations were randomly assigned and blocked so that all PPLs were observed twice and that each of the seven projects implementation was observed at least once. For project one, there were twelve steps; whereas, the other projects had eleven steps. This is because the beginning of project one was in the first week and there was an extra step to collect an initial check-in questionnaire, prior to the LC starting. There was a total of 20 observations completed, and the adherence to the steps was 100% across all observations.

Analysis plan

Preliminary analyses included descriptive statistics of the outcomes measures, as well as correlations between outcome measures. For comparisons across biology quiz scores, group membership was coded 0 = BC and 1 = LC. For comparisons across mathematics quiz scores, group membership was coded 0 = MC and 1 = LC. For comparisons across SSNS-A scales, group membership was coded 0 = LC, 1 = BC, and 2 = MC. Of the 198 students who enrolled across all conditions, 151 students completed the initial quizzes.

Primary analyses for the biology and mathematics quizzes were analyses of covariance (ANCOVA), where the dependent variable (DV) was the respective post-test quiz score, the independent variable (IV) was group membership (LC vs. BC and LC vs. MC, respectively), and the covariates were respective pre-test quiz, course instructor, and high school grade point average (GPA). Regression based models, such as ANCOVA models, are preferred for pre-post comparisons between groups. Covarying the pre-test protects against incorrectly evaluating intervention effects due to unaccounted group variance during the pre-test (Dimitrov and Rumrill 2003). These models also allow covariates to be considered simultaneously, in case there is non-equivalency on potential student and environmental factors related to academic performance (Theobald and Freeman 2014). Due to missing data from attrition, parameter estimates with jackknife robust standard errors were used. This provides a conservative estimate of the 95% confidence intervals around point estimates compared to techniques like bootstrap estimates (Efron 1981).

The primary analysis for the SSNS-A scales was a multivariate analysis of covariance (MANCOVA), where the DVs were the seven post-test SSNS-A scales, the IV was group membership (LC, BC, or MC), and the covariates were the SSNS-A pre-test scales. There were inconsistent statistically significant and low ($\rho \leq .20$) zero-order correlations between the scales and GPA, as well as if the student was a STEM major. Therefore, no additional covariates were included. Post-hoc pair-wise Bonferroni adjusted comparisons were made across groups for significant univariate comparisons after the omnibus multivariate test.

Results

The correlation matrix with means and standard deviations for all study measures is located in (Table 3). Unexpectedly, biology quiz pre- and post-test scores were significantly and negatively correlated; whereas, maths quiz pre- and post-test scores were positively and significantly correlated. All SSNS-A scales at pre-test were positively correlated with their respective post-test scales. However, the pre-post respective correlations between Performance and Self-efficacy did not reach statistical significance.

The results for the ANCOVA on the biology quiz indicated that there were significant differences in the biology post-test score between the LC and biology control group, $F(1, 38) = 8.68$, $p = .005$, $\eta_p^2 = .19$. Parameter estimates with robust standard errors indicated significantly greater scores for the LC group, $b = 15.60$ (6.68), 95%CI [2.08, 29.11], $t = 2.34$, $p = .025$, Cohen's $d = 0.76$. The group means and adjusted means are located in Table 4. Additionally, significant differences on the biology post-test quiz by biology instructor were indicated, $F(1, 38) = 12.28$, $p = .001$, $\eta_p^2 = .24$, but neither the pre-test quiz scores ($p = .432$) nor high school GPA ($p = .452$) were related to post-test scores.

The results for the ANCOVA on the mathematics quiz indicated that there were non-significant differences in the mathematics post-test score between the LC and mathematics control group, $F(1, 72) = 2.19$, $p = .143$, $\eta_p^2 = .03$. Parameter estimates with robust standard errors indicated non-significantly greater scores for the LC group, $b = 7.57$ (5.25), 95%CI [−2.90, 18.05], $t = 1.44$, $p = .154$. The group means and adjusted means are located in Table 5. Furthermore, significant differences in the mathematics post-test quiz were related to pre-test performance, $F(1, 72) = 9.12$,

Table 3. Pearson's r correlations with means and standard deviations between outcomes measures at pre-test and post-test.

	Pre-Test									Post-test								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Pre-Test																		
1. Biology Quiz	–																	
2. Maths Quiz	.26	–																
3. SSNS-A Knowledge	−.09	−.07	–															
4. SSNS-A Performance	−.06	−.01	**.35** ***	–														
5. SSNS-A Motivation	−.05	−.09	**.58** ***	**.36** ***	–													
6. SSNS-A Tools/Environment	−.18	−.07	**.37** ***	**.45** ***	**.52** ***	–												
7. SSNS-A Feedback Procedural	**−.32** **	−.07	**.35** ***	**.39** ***	**.41** ***	**.63** ***	–											
8. SSNS-A Feedback Rewards	−.25	−.06	**.37** ***	**.43** ***	**.41** ***	**.52** ***	**.65** ***	–										
9. SSNS-A Self-Efficacy	−.19	.01	**.54** ***	**.46** ***	**.59** ***	**.45** ***	**.45** ***	**.50** ***	–									
Post-test																		
10. Biology Quiz	**−.37** **	.00	.15	−.01	.18	.16	.25	.25	.14	–								
11. Maths Quiz	.13	**.37** **	−.13	−.02	−.09	−.03	.15	−.08	.01	.13	–							
12. SSNS-A Knowledge	.06	−.01	**.36** ***	.07	.11	.08	**.23** *	.17	.11	**.27** *	.13	–						
13. SSNS-A Performance	.18	.03	.11	.13	.11	.14	.07	.09	.09	.04	**.27** **	**.35** ***	–					
14. SSNS-A Motivation	.18	−.10	**.27** **	.03	**.28** **	**.20** *	.13	**.20** *	.11	.13	.08	**.60** ***	**.44** ***	–				
15. SSNS-A Tools/Environment	.17	−.07	.08	−.01	.13	**.32** ***	.17	.09	.01	**.29** *	.00	**.32** ***	**.38** ***	**.35** ***	–			
16. SSNS-A Feedback Procedural	.16	−.11	.10	−.01	.12	**.26** **	**.22** *	.13	.05	**.33** *	.13	**.43** ***	**.42** ***	**.42** ***	**.71** ***	–		
17. SSNS-A Feedback Rewards	.002	−.01	.15	−.02	.07	.12	.17	**.24** *	.01	**.37** **	.07	**.39** ***	**.45** ***	**.39** ***	**.60** ***	**.72** ***	–	
18. SSNS-A Self-Efficacy	.25	.10	**.26** **	.13	.11	.17	.09	**.20** *	.16	.12	.15	**.61** ***	**.54** ***	**.61** ***	**.41** ***	**.55** ***	**.54** ***	–
M	22.9	27.2	4.73	4.86	5.4	5.1	4.7	4.7	5.0	50.7	64.5	4.7	4.5	5.2	4.8	4.4	4.3	4.7
SD	11.7	16.8	0.7	0.7	0.7	0.8	0.9	0.9	0.9	19.3	19.2	0.7	0.7	0.8	0.8	1.0	1.0	1.0

SSNS-A = Student Support Needs Scale-Augmented.
*$p < .05$; **$p < .01$; ***$p < .001$

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p = .004, η^2_p=.11, and high school GPA, $F(1, 72) = 16.32$, $p < .001$, η^2_p=.19, but performance was unrelated to the algebra instructor (p = .437).

The MANCOVA for the SSNS-A scales at post-test between the three groups indicated an omnibus multivariate difference between groups, $F(14, 172) = 2.11$, $p = .013$, Wilk's Λ = .73. A follow-up univariate test indicated that there were statistically significant differences between groups on SSNS-A Performance on the post-test, $F(2, 92) = 3.30$, $p = .041$, η^2_p=.07. Bonferroni pair-wise comparisons indicated greater scores for the biology control group compared to the mathematics control group (p = .047; Cohen's d = 0.56). Additionally, a univariate test indicated that there were significant differences between groups on the SSNS-A Feedback Procedural scale for the post-test, $F(2, 92) = 3.83$, $p = .025$, η^2_p=.08. Bonferroni pair-wise comparisons indicated greater scores for the LC group compared to the mathematics control group (p = .024; Cohen's d = 0.81). The group means and adjusted means are located in (Table 6).

Discussion

The purpose of this study was to present the outcomes for a performance pyramid LC intervention delivered to college students enrolled in General Biology I at an HBCU. Students in the LCs had greater gains in biology knowledge when compared to students who took the course and received instruction as usual. LC students and students who took the College Algebra course with instruction as usual had similar gains in mathematics knowledge. Further, LC students reported more procedural feedback than did students in the MC group.

Course quiz outcomes

The greater growth for the LC students compared to the BC students on the biology quiz was expected. The adjusted means comparison indicated that the LC activities might have contributed to a 15-point performance difference in biology quiz scores. Conversely, the difference between the LC and MC groups did not reach statistical significance, although the adjusted means indicated an approximately 7-point performance difference in the mathematics quiz. It is possible that the LC intervention increased biology performance because the focus of the exercises was biology course specific. Whereas, additional activities directly related to the college algebra were not included, and might be necessary to improve mathematics performance.

However, our findings correspond with previous studies that indicate that subject specific LCs can increase subject exam performance from pre- to post-test by 63 to 167% (e.g., Lee, Khalil, and

Table 4. Comparison of biology control and participant learning community unadjusted and adjusted means on the biology post-test quiz.

Group	*N*	*M (SD)*	*Adj. M*	95%CI
Biology Control	25	41 (14.43)	45.1	[38.97, 51.23]
LC	18	66.39 (16.34)	60.7	[53.19, 68.20]
Total	43	51.63 (19.69)		

Pre-test value for the Biology Quiz = 23.26. LC = learning community.

Table 5. Comparison of mathematics control and participant learning community unadjusted and adjusted means on the mathematics post-test quiz.

Group	*N*	*M (SD)*	*Adj. M*	95%CI
Maths Control	63	65.08 (19.25)	63.95	[59.78, 68.11]
LC	14	66.43 (19.85)	71.52	[62.39, 80.66]
Total	77	65.32 (19.23)		

Pre-test value for the Maths Quiz = 28.31. LC = learning community.

Table 6. Comparison of Learning Community (LC) (n = 14), biology control (n = 29), and mathematics control (n = 59) unadjusted and adjusted means on the Student Support Needs Scale-Augmented (SSNS-A) Scales.

SSNS-A Scale	Group	*M (SD)*	*Adj. M*	95%CI
Knowledge	LC	4.67 (0.62)	4.68	[4.36, 5.00]
	Biology Control	4.61 (0.74)	4.71	[4.47, 4.94]
	Maths Control	4.74 (0.60)	4.69	[4.53, 4.85]
	Total	4.69 (0.64)		
Performance	LC	4.40 (0.81)	4.43	[4.06, 4.80]
	Biology Control	4.87 (0.54)	4.85	[4.59, 5.12]
	Maths Control	4.44 (0.70)	4.44	[4.26, 4.62]
	Total	4.55 (0.70)		
Motivation	LC	5.13 (0.87)	5.13	[4.79, 5.47]
	Biology Control	5.44 (0.56)	5.47	[5.23, 5.72]
	Maths Control	5.16 (0.62)	5.14	[4.98, 5.31]
	Total	5.23 (0.65)		
Tools/Environment	LC	5.14 (0.70)	5.14	[4.77, 5.52]
	Biology Control	4.94 (0.70)	4.89	[4.62, 5.16]
	Maths Control	4.73 (0.81)	4.76	[4.57, 4.95]
	Total	4.84 (0.77)		
Feedback Procedural	LC*	4.99 (0.86)	4.96	[4.50, 5.42]
	Biology Control	4.55 (0.80)	4.53	[4.19, 4.86]
	Maths Control	4.23 (0.93)	4.25	[4.02, 4.48]
	Total	4.43 (0.92)		
Feedback Rewards	LC	4.63 (1.04)	4.63	[4.11, 5.15]
	Biology Control	4.17 (0.94)	4.22	[3.84, 4.60]
	Maths Control	4.33 (1.02)	4.31	[4.05, 4.57]
	Total	4.33 (1.00)		
Self-Efficacy	LC	4.65 (0.98)	4.70	[4.20, 5.20]
	Biology Control	4.72 (0.86)	4.74	[4.38, 5.11]
	Maths Control	4.72 (0.95)	4.70	[4.45, 4.94]
	Total	4.71 (0.92)		

Pre-test value for the SSNS-A Knowledge = 4.68, SSNS-A Performance = 4.92, SSNS-A Motivation = 5.45, SSNS-A Tools/Environment = 5.11, SSNS-A FB Procedure = 4.63, SSNS-A FB Rewards = 4.57, SSNS-A Self-Efficacy = 5.04. LC = learning community.
*$p < .05$.

Boykin 2019). The within group increase for the LC group for this study had a 161% increase in biology quiz scores, compared to the BC group's 94% increase. While both groups demonstrated within group improvements, the LC group had a greater rate of improvement. Comparisons of LCs and instruction as usual for biology courses have indicated that biology course grades increase by .64 and .77 grade points out of 4.00 for the LC groups (Xu et al. 2018). We did not collect course grades, but a greater proportion of students in this study's LC scored 70% or greater on the post-test quiz (53%) when compared to the biology control group (3%). This could suggest that the LC activities increase biology knowledge, as well as pass rates on course assessments.

Performance pyramid student support needs

The only difference found when comparing LC students' perceptions of support needs to both control groups was for the SSNS-A Feedback Procedural scale. The LC students indicated that they received more information related to expectations and course performance than students in the MC group. This might be due to the LC students setting goals and logging performance on course work, which could have made them more aware of their course work feedback. It is unclear why this difference was only found between the LC and MC groups. Perhaps, the difference might be less apparent when scores are compared to the BC group, as the students could have found the biology course clearer and more easily mastered.

Alternatively, the differences observed could have been due to inflated type-I error from multiple comparisons. There were 21 pair-wise comparisons across the SSNS-A scales. The

Bonferroni correction used is a conservative adjustment to the alpha level, as it is likely to miss true positives and increase false negatives (Curran-Everett 2000). However, our supplementary analyses using the Benjamini-Hochberg false discovery rate (FDR; FDR = .05; Carbocation Corporation 2016) indicated that all pair-wise comparisons were non-significant. The FDR is useful when exploring a larger number of comparisons because it controls the number of falsely rejected differences and limits misclassified comparisons by adjusting p-values in proportion to their rank order (Benjamini and Hochberg 1995; Voelkl 2019). This incongruence between adjustments could indicate that further data collection is needed to determine the consistency of the observed effects (Saville 2003).

Limitations

There are notable limitations to this study. One limitation is the missing data, which we handled by using conservative standard error estimates. However, the missing data for the quizzes was attributed to missing the class day that the pre- or post-test was administered, due to absence, late registration or withdrawal from the course. Further, the missing data for the SSNS-A also included unanswered items or skipping the questionnaire in total. Further, there were 22 students initially enrolled in the LC. Four of the students withdrew from the intervention, and only 14 of the LC students completed the maths post-test. It is likely that the students who persisted in the LC and the courses did so because they had higher performance, which could reduce the range of quiz scores and inflate performance. Future effort will require possibly allowing for make-up opportunities to complete the biology and mathematics quizzes, as well as providing support for answering all survey items by encouraging students to ask for clarification on items and emphasising how they will help contribute to the field of STEM course support.

Another limitation is that a quasi-experimental design was used. The design allowed for students to self-select into the LC or control conditions. This might have contributed to observed and possibly unobserved differences between groups. In general, there were no differences between the groups on previous school success (i.e., high school GPA). Nonetheless, our data collection procedures were unlikely to capture all predictors or motivations for scholastic success between groups. To address these issues, further research using randomised controlled trials should be completed, which could guard against potential systematic differences between LC and control groups.

Moreover, the design compared supplementary instructional activities to instruction as usual. It could be reasoned that any additional, targeted repeated practice would improve outcomes. Therefore, additional studies regarding competing interventions or augmentations to the general curriculum might be needed in the future. Alternatively, the intervention used in this study did align with evidence-based recommendations for diverse STEM students, which call for improving the general curriculum as well as additional social and cross-discipline collaboration (Estrada et al. 2016). It could be that programme aligned with evidence-based recommendations for diverse STEM students could be compared to find the most efficacious and efficient.

Further, the survey and the SSNS-A should be reviewed to determine if they can better capture the students' perspectives. This would include reviewing and adjusting items, and conducting further psychometric studies. For instance, the low reliability coefficients for the SSNS-A Performance subscale, could signal that the scale might need to be revised. In addition, evaluations related to factor structure and validity are needed to further support the use or alteration of the SSNS-A.

Implications

The current study examined the preliminary outcomes for a LC intervention based on the theoretical structure of the performance pyramid. The initial outcomes appear promising for improving performance in biology courses when compared to instruction as usual. However, the impact on mathematics performance was less pronounced, as was an indication that students perceived more support related to the performance pyramid elements. Still, it is promising that the results are consistent with previous research that indicates subject specific LCs can improve performance in STEM subjects (Lee, Khalil, and Boykin 2019) and specifically biology (Xu et al. 2018). College biology programmes could consider LCs with the same types of activities when looking to increase student performance in their introductory biology course.

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