A Student-Centered, Entrepreneurship Development (ASCEND) Undergraduate Summer Research Program: Foundational Training for Health Research

Avis Jackson,[1†*] Sherita Henry,[2] Kevon M. Jackman,[3] Laundette Jones,[4] Farin Kamangar,[5] Niangoran Koissi,[6] Shiva Mehravaran,[7] Akinyele Oni,[8] Carroll Perrino,[9] Payam Sheikhattari,[10] Erika Whitney,[8] and Christine F. Hohmann[7,8†]

[1]Center for Predictive Analytics, Psychology Department, College of Liberal Arts, Morgan State University, Baltimore, MD 21251; [2]Department of Nursing, Hood College, Frederick, MD 21701, [3]Adolescent and Young Adult Medicine, Department of Pediatrics, Johns Hopkins University School of Medicine, Baltimore, MD 21205; [4]Department of Epidemiology and Public Health and Department of Pharmacology, University of Maryland School of Medicine, Baltimore, MD 21201; [5]Division of Research and Economic Development, Morgan State University, Baltimore, MD 21251; [6]Department of Chemistry, School of Computer, Mathematical and Natural Science (SCMNS), Morgan State University, Baltimore, MD 21251; [7]ASCEND Center for Biomedical Research, Morgan State University, Baltimore, MD 21251; [8]Department of Biology, School of Computer, Mathematical and Natural Science (SCMNS), Morgan State University, Baltimore, MD 21251; [9]Department of Psychology, College of Liberal Arts, Morgan State University, Baltimore, MD 21251; [10] Department of Public Health, Morgan State University and ASCEND Center for Biomedical Research, Morgan State University, Baltimore, MD 21251

ABSTRACT

Increasing the participation of students of African descent and other minoritized populations in the scientific workforce is imperative in generating a more equitable biomedical research infrastructure and increasing national research creativity and productivity. Undergraduate research training programs have shown to be essential tools in retaining underrepresented minority (URM) students in the sciences and attracting them into STEM and biomedical careers. This paper describes an innovative approach to harness students' entrepreneurial desire for autonomy and creativity in a Summer Research Institute (SRI) that has served as an entry point into a multiyear, National Institutes of Health Building Infrastructure Leading to Diversity (NIH BUILD)-funded research training program. The SRI was designed as an 8-week, student-centered and course-based research model in which students select their own research topics. We test here the effects of SRI training on students' science self-efficacy and science identity, along with several other constructs often associated with academic outcomes in the sciences. The data shown here comprise analysis of four different training cohorts throughout four subsequent summers. We show significant gains in students' science self-efficacy and science identity at the conclusion of SRI training, as well as academic adjustment and sense of belonging. SRI participants also displayed substantially improved retention in their science majors and graduation rates.

Daron Barnard, *Monitoring Editor*

Submitted Nov 9, 2021; Revised Oct 31, 2022; Accepted Dec 16, 2022

†These authors contributed equally to this paper. C.F.H., A.J., and S.M. were responsible for data generation, data analysis, and preparation of the manuscript. S.H., K.M.J., F.K., N.K., C.P., P.S., and E.W. worked with C.F.H. and A.J. on designing the original SRI Learning Objectives. C.P. was also instrumental in early mentor/mentee training efforts for the team. S.H., K.M.J., N.K., and E.W. worked as instructors for several cohorts of the SRI and helped shape the iterative curriculum redesign.

*Address correspondence to: Avis Jackson (Avis.Jackson@Morgan.edu).

CBE Life Sci Educ March 1, 2023 22:ar13

DOI:10.1187/cbe.21-11-0314

INTRODUCTION

Although recent years have seen modest gains in the number of underrepresented minority (URM) students who complete doctoral work and persist in science, technology, engineering, and mathematics (STEM) careers, African-American, Native American, Latinx, and other minority groups are still woefully underrepresented in the STEM and biomedical sciences fields (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011; President's Council of Advisors on Science and Technology [PCAST], 2012; Fiegener and Proudfoot, 2013;

Valantine and Collins, 2015; Valantine *et al.*, 2016; Gibbs and Marsteller, 2016; National Center for Science and Engineering Statistics (NCSES), 2020). As the U.S. population continues to diversify, disproportional underrepresentation in the STEM workforce not only presents a social justice issue but also poses a growing economic problem for the country (PCAST, 2012; Freeman and Huang, 2014). It has become well established that diverse teams are more creative, effective, efficient, and lucrative, resulting in higher-quality research, products, and health services (Herring, 2009; Hunt *et al.*, 2015). Thus, we must continue to emphasize the development and assessment of effective interventions to increase participation of all aspects of the U.S. population in STEM and biomedical research (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011; Meyers *et al.*, 2016; Valantine *et al.*, 2016).

Participation in authentic undergraduate research experiences enhances STEM retention and students' interest in pursuing research and graduate degrees (Seymour *et al.*, 2004; Lopatto, 2007; Russell *et al.*, 2007). This has shown to be important, in particular, for students from URMs (Nagda *et al.*, 1998; Schultz *et al.*, 2011; Jeffe *et al.* 2012; Hernandez *et al.*, 2018a).

The research literature suggests that, for URM, first-generation, and female students, sociopsychological factors are as important as academic preparedness in generating STEM persistence and self-efficacy (Estrada *et al.*, 2011; Merolla and Serpe, 2013; Spitzer and Aronson, 2015; Byars-Winston *et al.*, 2016; Tibbetts *et al.*, 2016). Factors such as science self-efficacy, sense of belonging, and science identity have been characterized as essential and interrelated cognitive and emotional predictors in URM students' decisions to persist in their science education. Studies suggest that these factors are leading mediators and moderators in effective undergraduate science training for URM students (Chemers *et al.*, 2011; Merolla and Serpe, 2013; Trujillo and Tanner, 2014; Lujan and DiCarlo, 2017; Hernandez *et al.*, 2018b). Students' sense of autonomy (or ownership in their learning) further strengthens science identity and self-efficacy (Lujan and DiCarlo, 2017). For first-generation undergraduate students, in particular, the personal and social relevance of their research is of great importance (Thoman *et al.*, 2013).

At Morgan State University (MSU), we have developed an innovative training model, A Student-Centered, EntrepreNeurship Development (ASCEND), geared at building student science identity, self-efficacy, and health science knowledge through interdisciplinary training that emphasizes team building and collective ownership of research ideas. This training model is based on the hypothesis that increasing students' autonomy in the selection of research topics, along with community building, will enhance their science identity and self-efficacy, enhance retention to graduation, and ultimately result in committed young researchers with leadership ability (Kamangar *et al.* 2017, 2019).

The Summer Research Institute (SRI) at the center of this paper represents the first and foundational step in the ASCEND training model developed under the National Institutes of Health Building Infrastructure Leading to Diversity (NIH BUILD) Initiative at MSU. The ASCEND model differs from most other research training programs in that it abandons the apprenticeship model for a group-based, student-centered training model that promotes entrepreneurial attributes such as creativity, autonomy, proactivity, strategizing, risk taking, and personal responsibility (Brockhaus, 1982; Bird, 1988; Hisrich, 1990; Ghosh and Raharam, 2015; Robinson *et al.*, 2016; Rosique-Blasco *et al.*, 2016).

The SRI has been geared, in particular, toward retention of lower-division undergraduate URM students in biomedical sciences with the long-term objective of encouraging postgraduate training and health science careers, which is the focus of the subsequent years of training in the ASCEND model. In the first 2 years of college, students make crucial decisions to continue or withdraw from STEM majors (PCAST, 2012). For URM students, interest in STEM majors is initially equivalent to that of other groups, but disproportionately more URM and female students withdraw from STEM disciplines (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011; PCAST, 2012; Meyers *et al.*, 2018). Thus, strengthening research knowledge and self-efficacy along with science identity in lower-division URM students should increase the number of students who are successfully retained to graduate in their science majors as well as prepare them for subsequent research training in the ASCEND Program with a focus on graduate school preparedness.

This study focuses on assessing the effect of the ASCEND SRI in measures of identity, attitude, and aspirations, including items related to academic self-concept, scientific self-efficacy, science identity, adjustment to college, engagement in research, and satisfaction with faculty mentorship; participation in academic and professional student organizations; and intent to pursue a career in biomedical research. We hypothesized that our training approach would result in increased science self-efficacy and science identity in SRI participants and therewith improved retention in their majors and subsequent college completion.

The survey questions and constructs used here were developed after an extensive literature review and are also included in the Cooperative Institutional Research Program surveys administered by the Higher Education Research Institute (HERI; Eagan *et al.*, 2017; McCreath *et al.*, 2017). In particular, the questions used here were part of consensus instruments that were applied to all BUILD-supported (NIH General Fund U54) institutions via the Consortium Evaluation Center (CEC), which guided individual BUILD site assessment with Hallmarks of Success (McCreath *et al.*, 2017; NIH, 2019)

MATERIALS AND METHODS

Participants

Participants for the SRI were recruited from among lower-division undergraduates across STEM and social behavioral sciences. Students were required to have a minimum grade point average (GPA) of 2.8 and to have completed a minimum of 20 but no more than about 60 credit hours (counting toward their major) at the start of the summer. Because the program was federally (NIH) funded, students also provided documentation of U.S. citizenship or permanent residency. An 11-item rubric was devised to assess student suitability for the SRI training program. Points were allocated for being first-generation college attendees, being eligible for a Pell grant, having disability status, and having participated in community or volunteer

TABLE 1. Cohort descriptive data up to Spring 2021

	Cohort 1 (2015)	Cohort 2 (2016)	Cohort 3 (2017)	Cohort 4 (2018)	Total mean
N	28	27	29	21	26%
Female/males	76%/24%	79%/21%	71%/29%	52%/48%	69.5%/30.5%
In-state residency	78%	88%	57%	86%	77.25%
Pell Grant status	61%	62%	75%	71%	67%
Financial aid	89%	88%	82%	95%	88.5%
Merit Scholarship	37%	38%	39%	38%	38%
Family education[a]	28	23	25	21	24
No college	—	22%	16%	14%	17%[b]
Sibling in college	—	35%	24%	19%	26%[b]
College degree	—	61%	76%	81%	73%[b]
Some	96%[c]	22%	24%	43%	30%[b]
Grad/prof	—				
Rising classification[d]	Sophomore	Sophomore	Sophomore or junior	Sophomore or junior	Sophomore
Major	Biology: 11 Psychology: 7 Nursing: 2 Electrical engineering: 2 Health education, medical technology, natural sciences, physical education, social work: 1 each	Psychology: 9 Biology: 6 Electrical engineering: 3 Nursing: 2 Environmental health, health, pharmacy, political science, nutritional science, and social work: 1 each	Biology: 15 Psychology: 6 Medical technology: 2 Nursing, social work, sociology, computer science: 1 each Community college health sciences major: 1	Biology: 9 Psychology: 4 Nursing: 2 Medical technology, nutritional science, computer science, health education, and physical education: 1 each	Biology: 10 Psychology: 6.5 Nursing: 2 Medical technology: 1 Electrical engineering: 2 Social work: 1
Proposals submitted/ accepted	8/6	6/6	6/5	5/5	6.25/5.5
Graduation rates					
4-year	24%	38%	33%	68%	38%
6-year	69%	50%	89%	—	69%[e]
Totals[f]	97%	96%	89%	84%	92%
Persistence in original major	92%	100%	98%	100%	97.5%

[a]Number of respondents.
[b]Only cohorts 2–4 were used to compute.
[c]Question asked if applicant was first to attend college.
[d]Rising classifications reflect the upcoming Fall semester.
[e]Excludes cohort 4.
[f]From Spring 2021.

work. Recommendation letters were scored for evidence of applicants being self-motivated and proactive, having leadership potential, and showing the ability to work well in a team. Students were asked to provide essay responses to five questions that focused on their interest in health research and their intent to engage in graduate education. One question also inquired about the students' prior experience with overcoming personal and academic obstacles to assess resilience. Applicants were rated and ranked based on the above mentioned 11-item rubric. A maximum of 30 students were admitted into the SRI each year, except for cohort 4, when the maximum was 20. Not all students accepted into the program enrolled, but all enrolled students completed their training in the SRI. Participant demographics for each cohort are listed in Table 1.

Training Strategy and Components

The ASCEND SRI used a course-based undergraduate research experience–like approach instead of individual student placement in research labs (Auchincloss *et al.*, 2014; Shapiro *et al.*, 2015; Elgin *et al.*, 2016; Staub *et al.*, 2016). Instructions were based on evidence-based, student-centered approaches and relied heavily on group work (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011). Students were supported by near-peer mentors (graduate students or senior undergraduates) with substantial research experience. A group of five instructors with disciplinary grounding in biology, chemistry, public health, and psychology comprised the instructional team.

The curriculum combined cooperative learning with hands-on research modules focused on health topics (see list in Supplemental Table A4). Students were introduced to scientific thinking and the research process as they worked in interdisciplinary groups. Instructors modeled different disciplinary approaches to health science research using scientific literature as well as short, hands-on research projects, both lab and field based. Students were challenged to identify real-world health science problems and propose solutions. Implicit in the SRI entrepreneurial focus are achievement orientation, becoming a greater (intellectual) risk taker, and developing emotional resilience (Bird, 1988; Hisrich, 1990; Ghosh and Raharam, 2015; Robinson *et al.*, 2016).

We thus aimed to cultivate a growth mindset in students as a means to enhance their personal self-efficacy (Trujillo and Tanner, 2014; Spitzer and Aronson, 2015; Claro *et al.*, 2016; Byars-Winston and Rogers, 2019).

The curriculum had four sections: "I. Introduction to Health and Health Research," "II. Basic Research Methodology," "III. How to Choose a Research Topic," and "IV. How to Write a Research Proposal." Each section comprised a set of learning objectives that were assessed using rubrics in analyzing students' written or oral deliverables, many of which were team based, but others required individual submissions. These assessments were purely formative. Although students received extensive feedback from near-peer mentors and instructors on their work, no grades were given nor were scores shared with them.

The training culminated in research proposals, generated by interdisciplinary participant groups and based on research questions of the students' choice (see Supplementary Material Table A5). At the program's completion, the students presented their proposals orally and in writing to an audience including campus faculty and staff, among whom were academic deans, the university provost and president as well as NIH program officers. The written proposals were reviewed by an NIH-style "study section" composed of faculty, postdocs, and graduate students with relevant disciplinary knowledge. Members of these review sections were recruited from our research partner institutions, Johns Hopkins University and the University of Maryland School of Medicine, as well as from MSU. Proposals were scored and ranked. Proposals deemed meritorious based on their scores were further developed in the following semester and eventually "funded" internally by the BUILD grant, as students moved on in their training to become ASCEND research scholars (see Supplementary Material Table A5). As indicated previously, the SRI was designed as entry training for a subsequent 2-year interdisciplinary group-research training experience—the ASCEND Scholars Program (see Kamangar *et al.* 2017, 2019). Based on students' performance in the SRI and self-declared interest, on average, 76% of SRI participants over the course of the 4 years were selected to continue as ASCEND Scholars.

Summative performance outcomes were assessed via the students' final oral and written proposal presentations and comprised:

1. ability to review and synthesize research literature orally and in writing;
2. ability to communicate and present (orally) scientific information fluently and in an organized way; and
3. ability to define the purpose of a research proposal and demonstrate this understanding by generating a team-based proposal.

For a detailed list of learning objectives please see Supplemental Table A1. As shown in this table, many of the objectives in sessions I through IV were iterative. These learning objectives were deepened for each of the subsequent instructional sections, and criteria for performance outcomes were increased incrementally.)

Measures

Measures and assessment items used in this study were informed by the Consortium-wide Evaluation Plan (McCreath *et al.*, 2017), which is guided by the Hallmarks of Success (NIH, 2019) developed by the Diversity Program Consortium Coordination and Evaluation Center (DPC CEC, n.d.), of the National Institute of General Medical Sciences at NIH. Survey questions addressed constructs including perceptions of culture and environment, identity, attitude, and aspirations; the survey included items related to academic self-concept, scientific self-efficacy, science identity, adjustment to college, engagement in research and satisfaction with faculty mentorship, participation in academic and professional student organizations, and intent to pursue a career in biomedical research. In addition to these self-reported outcomes, we also employed an assessment of critical thinking skills—the Critical Thinking Assessment Test (CAT), which has been widely used across U.S. college student populations responses (Stein *et al.*, 2007, 2016). Analyses in this paper focus predominantly on the constructs: scientific self-efficacy, science identity, adjustment to college, university's contribution to research ability, academic self-concept, and belongingness. Descriptive analyses were conducted for all constructs showing differences (see Supplemental Table A2). To indicate sample mean predictability to the population mean, the standard errors are presented. To estimate variability and reliability of the sample, the standard deviations and Cronbach's alphas are reported.

Science self-efficacy was measured using an eight-item scale and a 10-point rating rubric, with "1" the lowest rating as "not at all confident" and "10" the highest as "absolutely confident." The Science Self-Efficacy construct in HERI surveys is defined as "a measure of students' confidence in their ability to conduct scientific research" and asks: "How would you rate your ability to: 'analyze data,' 'choose a research topic,' or 'work with others in a group'?" In cohort 1, the scale was introduced in the posttest to replace an ill-fitting Academic and Scientific Self-Efficacy questionnaire. For the remaining cohorts, the scale was administered at the beginning and end of the program to measure change (pre- and posttests). Moreover, the posttest also included a retrospective or reflective design component in which students were asked to rate what they thought their skill level was at the start of the SRI, now that they had completed their training (reflective test; see Supplemental Table A2). Additional questions were added for cohort 4 (2018). These questions included: "How would you rate your ability to: 'Use technical science skills (use of tools, instruments, and/or techniques),' 'Generate a research question,' 'Determine how to collect appropriate data,' 'Explain the results of a study,' and 'Use scientific literature to guide research'?" (see Supplemental Table A2).

Science identity was only analyzed for cohort 4 (2018). The science identity construct from the CEC (DPC CEC, n.d.) was added to the pre-reflective test, and post-test questionnaires. This construct, which was adopted by HERI in 2016 from previous work (Estrada *et al.*, 2011), is defined as "the extent to which students conceive of themselves as scientists," and the items include: "I have a strong sense of belonging to the community of scientists," "I derive great personal satisfaction from working on a team that is doing important research," "I think of myself as a scientist," and "I feel like I belong in the field of science." It asks students to what extent the statements are true of them, and responses are collected on a five-point Likert scale: strongly disagree = 1, disagree somewhat = 2, neutral = 3, agree somewhat = 4, and strongly agree = 5.

The academic adjustment construct included four items: "Develop close friendships with other students," "Develop effective study skills," "Adjust to the academic demands of college," and "Manage your time effectively." Each was measured with a four-point Likert scale: very difficult = 1, somewhat difficult, somewhat easy, and very easy = 4.

University's contribution to research ability was represented with one item: "This university has contributed to my ability to conduct research." The Likert scale ranged from strongly disagree = 1 to strongly agree = 5.

The academic self-concept construct measure asked participants to "compare themselves to an average person of the same age academic ability, drive to achieve, mathematical ability, and intellectual self-confidence." Likert five-point scale response choices included the comparison choices of lowest 10% = 1, below average, average, above average, and highest 10% = 5.

The belongingness items included: "I see myself as part of the campus community," "I feel a sense of belonging to this campus," "I feel that I am a member of this University," "I feel valued at this University," and "If asked, I would recommend this University to others." The Likert scale ranged from strongly disagree = 1 to strongly agree = 5.

The CAT proprietary instrument is managed by the Center for Assessment and Improvement of Learning at Tennessee Technological University (TTU, 2020). The 15-question paper assessment booklet requires handwritten, primarily short-answer responses (Stein *et al.*, 2007). The responses are scored by instructor teams using their rubric to assign points. Higher points are associated with evidence of more critical thinking displayed in the written responses.

Completion

Retention and graduation data were retrieved from the Office of Institutional Research at the university. Program admission required a GPA of 2.8 and between 20 and 60 credit hours. Retention at the university was defined as graduating or remaining enrolled at the institution as juxtaposed with leaving or transferring. Graduation rates for SRI participants were based on participants per sophomore year cohort of the year they participated in the SRI. Graduation rates for the university were based on first-time, full-time, degree-seeking freshman students for the freshman year of each cohort. For example, the freshman year of cohort 1 (2015) was Fall 2013.

Procedures

Questionnaires were administered on the first day (pretest) and last days (reflective and posttest) of the program for all cohorts. Reflective items asking students what they thought about their performance/knowledge/attitude in the beginning of the program, now that they had completed it, were collected directly after the same posttest questions. The CAT test was administered at the end of the SRI for cohort 1 (2015) but at the beginning and end of the SRI for cohorts 2 to 4. The student answer booklets were scored by MSU faculty and graduate students (some of whom were SRI instructors and near-peer mentors) trained in a CAT scoring workshop. The booklets subsequently were sent to TTU, which provided a results report of group means including national comparisons and the raw data used for further analysis. The survey questionnaires were administered electronically, and the CAT through a paper booklet.

All statistical analyses were conducted using IBM SPSS statistics software v. 24. Specific statistical tests are discussed together with the assessment for which they were conducted. Figures were generated using GraphPad Prism v. 5 with analogous statistical analyses. Institutional review board approval was obtained under the overall BUILD–ASCEND grant.

Data Analysis

For each year, we assessed within-cohort changes as gain (positive change from pre- to posttest) and, as applies, realistic gain (reflective to posttest) and realistic beginning (change from reflective to pretest). Realistic gain measures the difference of students' perception of themselves at the beginning, now that they have completed the program, compared with their perceptions of themselves at the end, for each construct. The measure is more "realistic," as it allows the students' knowledge of a construct in the context of the program to inform their self-measure, as compared with imagining the construct's meaning in the pretest. Realistic beginning is the difference between the gain and realistic gain. It measures the difference of the student's pretest score without knowledge of the program to the reflective score, allowing the students to measure themselves more accurately on the construct as they reflect on a knowledge-informed construct. It represents the students' initial estimation error. The constructs of interest included: science self-efficacy, science identity, academic adjustment to college, belongingness, academic self-concept, university contribution to research ability, and critical thinking. In addition, we determined the potency of each construct with pooled data across all cohorts. Finally, we evaluated changes between cohorts of different individuals on each of the measures that informed gain and relative gain scores in order to learn about the benefits of the specific measures across each cohort and the impact of program improvements. It is important to highlight that the iterative yearly program refinements are based on distinct cohorts and as such any changes may be the result of either program improvements or those inherent differences.

Analysis Plan. The Wilcoxon signed ranks (W) test was used for gain scores (posttest minus pretest) and realistic gains (posttest minus reflective) to compare within-cohort paired sample data for each measure and to assess construct efficacy with pooled data across all cohorts. Each of the four cohorts was an independent sample; for between-cohort analyses, the Kruskal-Wallis H one-way analysis by ranks (KWH) was used as an analogue to the independent groups one-way analysis of variance (Siegel and Castellan, 1988). Difference scores were computed and used in the analyses of between-cohort constructs (see Supplemental Table A3). For each pair and omnibus test in which group average rank differences were found, the sample size, medians, range, adjusted p values, standardized z-test scores, computed effect sizes, and r values were reported (see Tables 2 and 3; Field, 2013, pp. 236–257).

Data Cleaning. Before the analysis was conducted, student's pre/post evaluation data were matched, examined for data entry accuracy, missing values, univariate and multivariate outliers, normality of distribution and fit for the test assumptions of multivariate analysis. Data were reviewed for each cohort across each of the pre/post evaluations of attitude and skills. Three negatively skewed outliers were adjusted to nearest larger score.

TABLE 2. Pooled construct paired gains and reflective gains (between cohort)

Variable[a]	Post – Pre/Post – Reflective/Reflective – Pre *N* ranks	Median	Range	*z*[b]	*p*[c]	Effect size[d]	r^2 = % of variance explained
SSE gain	101 – 73	64 – 57	63 – 61	–4.987	0.000	Medium	0.14
SSE realistic gain	101 – 101	53 – 64	72 – 63	–5.165	0.000	Medium	0.13
SSE realistic beginning	101 – 73	53 – 57	72 – 61	3.334	0.001	Small to medium	0.06
AcadAdj gain	73 – 101	10 – 12	10 – 9	4.536	0.000	Medium	0.12
ASC gain	102 – 101	16 – 16	9 – 9	–0.356	0.722 ns	Small	0.00
Belongingness gain	102 – 101	20 – 21	15 – 17	2.158	0.031	Small	0.02
CAT gain	73 – 89	13 – 15	24 – 18	1.458	0.145 ns	Small	0.01
UC gain	102 – 101	3 – 5	4 – 4	6.765	0.000	Large	0.23

[a]AcadAdj, academic adjustment; ASC, academic self-concept; SSE, science self-efficacy; UC, university contribution. Gain = post minus pre scores. Realistic gain = reflective minus post scores. Realistic beginning = reflective minus pre scores or initial estimation error.
[b]*z*-score.
[c]Probability value.
[d]Effect sizes: medium = 0.30; large = 0.50; huge = 0.70 (Cohen, 1988).

No multivariate outliers were found. Homogeneity of variance, sphericity, and homogeneity of variance–covariance matrices assumptions were all violated. With parametric assumption violations, the corresponding nonparametric statistics were used for the assessment of changes within the constructs.

For analyses of all cohorts for each measure, summed values were created into indices for the constructs measured with more than one item or question (science self-efficacy, science identity, academic self-concept, belongingness, and critical thinking). Difference scores were created from the indexed data to assess change over program duration. The science self-efficacy index scores include three test measurements: pre, post, and Reflective. These difference scores were created for post minus pre- (gains) and for post minus Reflective (realistic gains). For cohort 1 (2015), only realistic gain scores were available, as the pretest was not administered. Cohort 4 (2018) also included Reflective questions for science identity. Difference scores were assessed for normality. Two difference scores were found to be extremely skewed and were adjusted to meet minimum normality requirements (Tabachnick and Fidell, 2007, p. 77). Homogeneity of variance, sphericity, and homogeneity of variance–covariance matrices assumptions were all violated. Because parametric assumptions were violated by the data, nonparametric Kruskal-Wallis independent one-way analysis by ranks was employed. A matched data set without corrections for outliers or normality was created and used for the analysis.

RESULTS

The data analyses within each cohort showed significant gains and realistic gains in science self-efficacy across cohorts. In addition, cohorts 3 and 4 expressed a greater ease with academic adjustment to college. Added science self-efficacy and realistic science identity questions asked of cohort 4 (2018) showed increased values for each question in both constructs.

The data analyses between cohorts show significantly lower science self-efficacy for cohort 1 (2015) compared with the other three cohorts. Finally, students in cohort 2 (2016) on average had less belief that the university contributed to their ability to do science than cohort 3 (2017). Low to moderate correlations between all constructs across cohorts are shown (see Table 4), except for critical thinking. The CAT showed no relationship with either of the other constructs.

Science Self-Efficacy

Overall, the students' science self-efficacy began with a lower average median (Mdn = 57.0) compared with what they showed at the end (Mdn = 64.0); however, their perception of their science self-efficacy at the beginning of the program was even lower (Mdn = 53.0). Pooling data across all the cohorts, the science self-efficacy post score was significantly higher than the pre score; the reflective score was significantly lower than both the post and the pre scores (see Table 2).

Within-Cohort Assessment. As illustrated in Figures 1 and 2, significant gains and realistic gains were found with the science self-efficacy measure for each cohort, including the additional questions for cohort 4 (2018; see also Table 3). The scale reliabilities Cronbach's alpha for eight items (three and five additional items for cohort 4 additional questions) ranged from 0.56 to 0.89, with all but one reliability greater than 0.74. Excluded from this finding is the first cohort (2015), which was not administered a pretest for the science self-efficacy measure. Nonetheless, the students' reflections to the beginning of the program and their posttest impressions showed significant gains and realistic gains.

Between-Cohort Assessment. Omnibus testing of each factor across all cohorts determined significant differences for science self-efficacy, KWH (3) = 35.680, $\rho < 0.000$. Post hoc Bonferroni-corrected pairwise comparisons were conducted (see Supplemental Table A3). Three bivariate cohort combinations were found to have significantly different mean ranks. Cohort 1 (2015) had on average lower mean ranks than cohorts 2, 3, and 4 (2016, 2017, and 2018): between cohort 1 (2015) and 2 (2016), adj. $\rho < 0.001$, $z = -3.671$, $r = -0.51$; cohort 1 (2015) and 3 (2017), adj. $\rho < 0.000$, $z = -5.058$, $r = -0.68$; and cohort 1 (2015) and 4 (2018), adj. $\rho < 0.000$, $z = -5.100$, $r = -0.73$. Moderate correlations between all constructs across all cohorts are shown (see Table 4).

Science Identity

Science identity was not measured in the first three cohorts (1–3, 2015–2017). However, cohort 4 (2018) included measurement of several items representing a science identity construct (DPC CEC, n.d.).

TABLE 3. Significant construct paired gains and reflective gains (within cohort)

Variable[a]	Post – Pre/Post – Reflective/Reflective – Pre						r^2 = % of variance explained
	N ranks	Median	Range	z[b]	p[c]	Effect size[d]	
SSE							
2015							
Gain (only posttest)	—	—	—	—	—	—	—
Realistic gain	28 – 28	64.0 – 66.0	63 – 45	1.666	0.096 ns	Very small	0.05
Realistic beginning (only posttest)	—	—	—	—	—	—	—
2016							
Gain	24 – 25	59.5 – 66.0	46 – 35	−2.598	0.028	Medium	0.14
Realistic gain	25 – 25	45.0 – 66.0	56 – 35	−5.196	0.000	Huge	0.54
Realistic beginning	25 – 24	45.0 – 59.5	56 – 46	−2.598	0.028	Medium	0.14
2017							
Gain	28 – 27	56.0 – 66.0	61 – 28	3.062	0.007	Medium	0.17
Realistic gain	27 – 27	54.0 – 66.0	54 – 28	−3.266	0.003	Medium to large	0.20
Realistic beginning	27 – 28	54.0 – 56.0	54 – 61	−0.100	0.920 ns	None	0.00
2018							
Gain	21 – 21	57.0 – 66.0	44 – 24	2.469	0.041	Medium	0.15
Realistic gain	21 – 21	42.0 – 66.0	59 – 24	3.395	0.002	Large	0.27
Realistic beginning	21 – 21	42.0 – 57.0	59 – 44	−5.864	0.000	Huge	0.82
2018 Added questions							
Gain	21 – 21	107.0 – 89.0	65 – 36	3.549	0.001	Large	0.30
Realistic gain	21 – 21	107.0 – 68.0	65 – 95	−5.941	0.000	Huge	0.84
Realistic beginning	21 – 21	68.0 – 89.0	95 – 36	2.392	0.050	Medium	0.14
Science identity		Post – Pre					
2018							
Gain	21 – 21	17.0 – 9.0	8 – 6	4.028	0.000	Large	0.62
Realistic gain	21 – 21	17.0 – 14.0	8 – 9	3.577	0.000	Large	0.55
Realistic beginning	21 – 21	14.0 – 9.0	9 – 6	3.912	0.000	Large	0.60
AcadAdj		Post – Pre					
2015 Gain (only posttest)	28	11.0	8	—	—	None	0.00
2016 Gain	25 – 28	11.0 – 8.5	9 – 9	−0.483	0.629 ns	None	0.00
2017 Gain	27 – 28	12.0 – 8.5	8 – 5	−4.127	0.000	Large	0.56
2018 Gain	21 – 21	14.0 – 11.0	6 – 7	−3.398	0.001	Large	0.52
University contribution							
2015 Gain	28 – 28	5.0 – 3.0	2 – 3	−3.802	0.000	Small	0.26
2016 Gain	25 – 25	5.0 – 3.0	3 – 2	−4.075	0.000	Medium	0.33
2017 Gain	27 – 28	5.0 – 4.0	4 – 4	−2.643	0.008	Small	0.13
2018 Gain	21 – 21	4.0 – 4.0	1 – 4	−2.951	0.003	Small	0.21
Academic self-concept							
2015 Gain	28 – 28	16.0 – 16.5	7 – 7	−0.116	0.908 ns	None	0.00
2016 Gain	25 – 25	17.0 – 18.0	7 – 9	−0.909	0.364 ns	None	0.02
2017 Gain	27 – 28	16.0 – 16.0	9 – 9	−0.703	0.482 ns	None	0.01
2018 Gain	21 – 21	17.0 – 16.0	7 – 8	−1.828	0.068 ns	Small	0.08
Belongingness							
2015 Gain	28 – 28	22.0 – 20.5	10 – 13	−2.628	0.009	Small	0.12
2016 Gain	25 – 25	21.0 – 21.0	8 – 11	−0.343	0.731 ns	None	0.00
2017 Gain	27 – 28	22.0 – 20.0	17 – 15	−1.677	0.094 ns	Very small	0.05
2018 Gain	21 – 21	19.0 – 20.0	13 – 12	−0.980	0.327 ns	None	0.02
CAT		Post – Pre					
2015 Gain (only posttest)	17	18.0	14	—	—	None	0.00
2016 Gain	24 – 24	12.50 – 12.0	18 – 17	0.000[e]	1.000 ns	None	0.00
2017 Gain	27 – 28	15.0 – 12.0	12 – 18	2.507	0.012	Medium	0.21
2018 Gain	21 – 21	16.0 – 15.0	16 – 17	−0.356	0.722 ns	None	0.00

[a]AcadAdj, academic adjustment; SSE, science self-efficacy. Gain = post minus pre scores. Realistic gain = post minus reflective scores. Realistic beginning = reflective minus pre scores or initial estimation error.
[b]z-score.
[c]Probability value.
[d]Effect sizes: medium = 0.30; large = 0.50; huge = 0.70 (Cohen, 1988).
[e]The sum of negative ranks equals the sum of positive ranks.

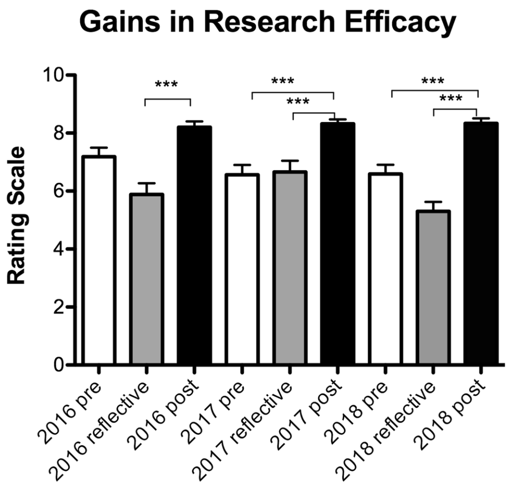

FIGURE 1. Overall gains and realistic gains in science self-efficacy for all cohorts with reflective data. Cohort 2 (2016) shows only realistic gains, while, Cohorts 3 & 4 show both gains and realistic gains. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Within-Cohort Assessment. Science identity for cohort 4 (2018) showed significant gains with post to reflective comparisons (see Figure 3). Combined questions also showed significant gain, realistic beginning, and realistic gain (see also Table 3). The scale reliabilities Cronbach's alpha for the three (pre) and five (post and reflective) items for cohort 4 questions ranged from 0.74 to 0.81.

Between-Cohort Assessment. With only one cohort measurement, omnibus testing of each factor across all cohorts was not computed for science identity. Low correlations between constructs in cohort 4 (2018) were found to range from –0.116 with science self-efficacy to –0.238 with academic self-concept.

Academic Adjustment

Overall, the students began the program with a lower average median (Mdn = 10.0) than they showed at the end (Mdn = 12.0). Pooling data across all the cohorts, the post score was significantly higher than the pre score (see Table 2).

Within-Cohort Assessment. Academic adjustment scores showed significant gains for cohorts 3 (2017) and 4 (2018; see Table 3). The scale reliabilities Cronbach's alpha for the four items ranged from 0.25 to 0.78, with pretests from cohorts 3 and 4 below 0.65. Figure 4 shows academic adjustment comparisons of pre to post pairs by questions representing this construct.

Between-Cohort Assessment. Omnibus testing of each factor across all cohorts determined significant differences for academic adjustment, KWH (2) = 19.868, $\rho < 0.000$ (see Supplemental Table A3). Post hoc Bonferroni-corrected pairwise comparisons were conducted. Two bivariate cohort combinations were found to have significantly different mean ranks. Cohort 2 (2016) had on average lower mean ranks than cohorts 3 and 4 (2017 and 2018): between cohort 2 (2016) and 3 (2017), adj. $\rho < 0.000$, $z = -4.237$, $r = -0.59$; and cohort 2 (2016) and 4 (2018), adj. $\rho = 0.001$, $z = -3.306$, $r = -0.49$. Small correlations between constructs across are shown (see Table 4).

Critical Thinking (CAT)

Overall, the students began the program with a lower average median (Mdn = 13.0) than they showed at the end (Mdn = 15.0). Pooling data across all the cohorts, the post scores were not significantly higher than the pre scores (see Table 2).

Within-Cohort Assessment. CAT scores, which presented with a broad range, only showed significant gains in pre/post assessments in one cohort (cohort 3, 2017; see Figure 5 and Table 3). For cohort 1, we only had post scores. The scale reliabilities Cronbach's alpha for the 15 items ranged from 0.11 to 0.65, with the lowest and highest reliabilities in pre- and posttest, respectively, for cohort 4. Construct differences were not seen for between-cohort assessment (see Supplemental Table A3). Low correlations between all constructs across are shown (see Table 4).

University Contribution to Doing Science

Overall, the students began the program with a lower average median (Mdn = 3.0) than they showed at the end (Mdn = 5.0). Pooling data across all the cohorts, the post score was significantly higher than the pre score with a large effect size (see Table 2).

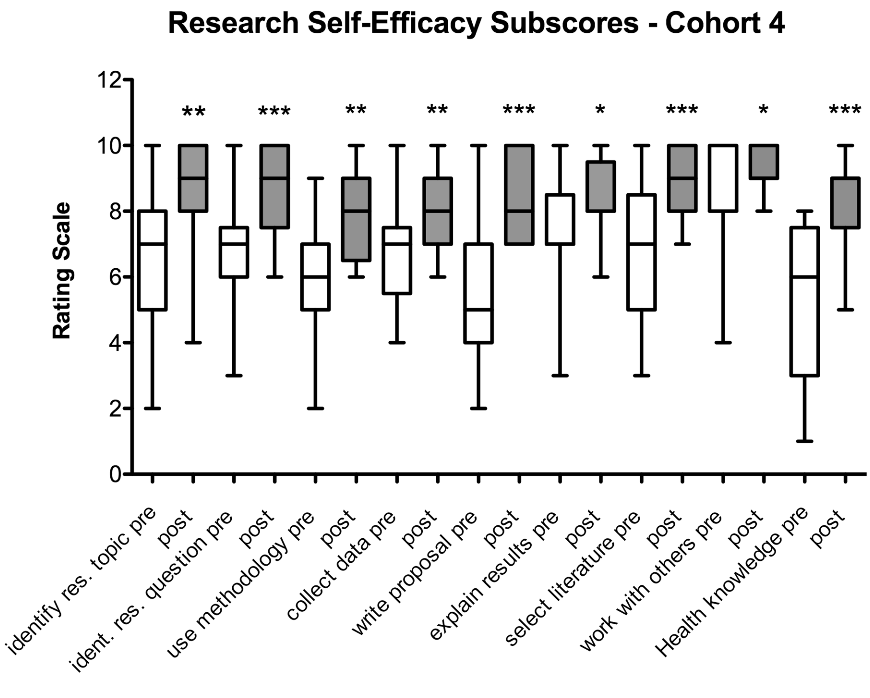

FIGURE 2. Gains in science self-efficacy for each individual question in Cohort 4. All individual questions show significant gains in the post-test compared to the pre-test in this cohort although significance levels varied. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 4. Bivariate correlations (*T*) of posttest scores across all cohorts[a]

Construct[b]	1	2	3	4	5	6
1. Belongingness, $n = 101$	1.000					
2. University contribution, $n = 101$	0.284**	1.000				
3. Science self-efficacy, $n = 101$	0.228**	0.231**	1.000			
4. Academic adjustment, $n = 101$	0.119	0.182b*	0.205**	1.000		
5. Academic self-concept, $n = 101$	0.292**	0.177*	0.332**	0.137	1.000	
6. Critical thinking (CAT) $n = 79$	0.026	0.007	−0.080	0.035	−0.008	1.000

[a]T = Kendall's tau. Correlation is significant at: **0.01 level (two-tailed); *0.05 level (two-tailed).
[b]n = sample size.

Within-Cohort Assessment. University contribution showed significant gains on the one question available across all cohorts. Unsurprisingly, students felt more strongly that the university contributed to their ability to conduct research at the end of the program compared with the beginning (see Table 3).

Between-Cohort Assessment. Omnibus testing of each factor across all cohorts determined significant differences for university contribution to doing science, KWH (3) = 12.206, $\rho = 0.007$ (see Supplemental Table A3). Post hoc Bonferroni-corrected pairwise comparisons were conducted. One bivariate cohort combination had significantly different mean ranks. Cohort 2 (2016) had on average lower mean ranks than cohort 3 (2017), adj. $\rho = 0.006$, $z = 3.287$, $r = 0.46$. Low correlations between constructs across cohorts are shown (see Table 4).

Academic Self-Concept

Overall, the students began the program with the same average median (Mdn = 16.0) than they showed at the end (Mdn = 16.0; see Table 2). Construct differences were not seen for within-cohort assessment and between-cohort assessment (see Supplemental Table A3). Low to moderate correlations between constructs across are shown (see Table 4).

Belongingness

Overall, the students began the program with a slightly lower average median (Mdn = 20.0) than they showed at the end (Mdn = 21.0). Combined across all the cohorts, the post score was significantly higher than the pre score (see Table 2). Construct differences were not seen for within-cohort assessment and between-cohort assessment (see Supplemental Table A3). Low correlations between constructs across are shown (see Table 4).

Completion

For all four cohorts, 99% completed the program, and 83% continued in ASCEND and became ASCEND Scholars—the next training level. Overall retention at the university for program participants was 87% compared with 63% university-wide averaged over the 4 program years. Several students transferred to other universities. The 4-year SRI graduation rate[1] was 38% compared with the university 4-year graduation rate[2] of 19.8%, and the 6-year SRI graduation rate was 75% compared with 45% for the university.[3] Overall, 97% of the SRI participants graduated.[4] Of those who completed the SRI and have graduated over the four cohorts, an average of 97% continued in their sciences or social sciences majors.

DISCUSSION

Our long-term objective is to increase the number of students at MSU who successfully transition into graduate school and enter the health science research workforce. The current study was designed to ascertain whether an entrepreneurship-based interdisciplinary summer research training experience could increase students' science self-efficacy and science identity and therewith retention for lower-division URM undergraduates in biomedical sciences. We assessed these parameters by individual cohort, across all cohorts, and also by the constructs themselves, using a cross-sectional and longitudinal design. The data shown here support our hypothesis that the BUILD–ASCEND SRI program—through student-centered activities, interdisciplinary group experiences, supported hands-on research experiences, and promoting entrepreneurial attributes in pursuing self-generated research questions—enhanced participants' science self-efficacy and science identity (cohort 4, 2018) to sustain interest in biomedical research careers. In addition, our data show that the SRI experience increased students' academic adjustment and sense of belonging, both factors likely related to increased retention and graduation rates.

Our results show robust increases in science self-efficacy as well as science identity for cohort 4. Science self-efficacy grew across the cohorts, as we fine-tuned our curriculum. Although recruited from the same demographics, each cohort had a somewhat unique analysis profile, illustrating the diversity among students' prior experience and mindset. Retention in STEM and social/behavioral sciences disciplines and graduation rates of SRI participants across all cohorts was substantially greater than at the MSU overall. Our outcomes are consistent with models proposed by Chemers *et al.* (2001) and Frantz *et al.* (2017), wherein simultaneous increases in self-efficacy and science identity in research-based programs predict increased persistence in STEM fields at least through the baccalaureate degree. Our data are also consistent with observations by Wei and Woodin (2011) that interventions other than the typical apprenticeship-type training model can be very effective research training tools, particularly if they provide students with a sense of "responsibility and ownership."

[1]SRI graduation rate is for all SRI participants.
[2]University graduation rate is for first-time, full-time, degree-seeking students beginning as freshmen.
[3]The 6-year rate includes the 4-year graduates.
[4]Total number of graduates includes from other institutions.

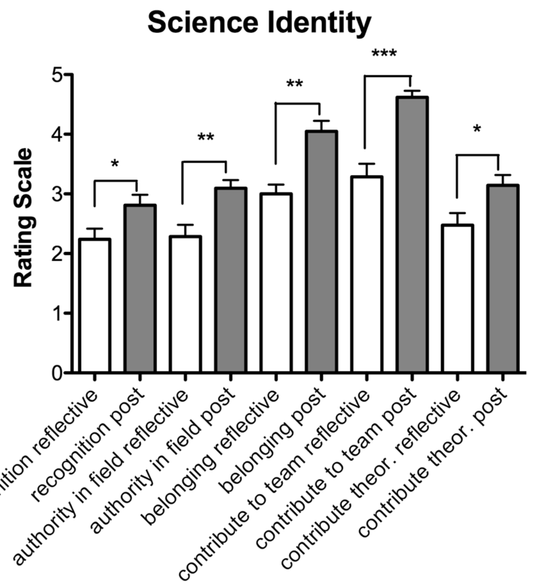

FIGURE 3. Realistic gains in Science Identity for Cohort 4 (2018). Each question shows growth from reflective-test to post-test. Theor. = theoretical. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Science self-efficacy is associated with stamina in the face of aversion or disappointment, a willingness to cope and extend effort due to confidence, and an expectation of success in STEM and the social sciences and is predictive of persistence and completion in those fields (Bandura, 1977; Lent *et al.*, 2005; Chemers *et al.*, 2011; Estrada *et al.*, 2011). It is noteworthy within this context that we have observed in a prior qualitative study that students struggled emotionally and in their attitudes in earlier phases of the SRI but showed elevated positive affect and thinking toward the conclusion of the summer experience (Jackson *et al.*, 2018). Thus, gains may require such a struggle.

The student's science self-efficacy consistently improved from pretest to posttest. Importantly, science self-efficacy showed substantial realistic gains between post- and reflective tests. It has often been shown that students initially overestimate their abilities and performance (Serra and DeMarree, 2016), especially in STEM courses (Lindsey and Nagel, 2015), which may explain the more significant p values and meaningful effect sizes and explained variance (see Table 3). These results are related to findings that prediction and anticipation of adhering to high academic expectations and rules in a demanding STEM major were related to high confidence or self-efficacy (Chemers *et al.*, 2001; Lent *et al.*, 2003, 2005). Additionally, Robbins *et al.* (2004) showed in a meta-analysis that academic self-efficacy was related to and a strong predictor of retention. However, Aronson, and Inzlicht (2004) showed that stereotype-vulnerable African Americans indicate, in real time, lower and fluctuating academic self-efficacy in areas of interest compared with less vulnerable African Americans and whites. Thus, introducing an opportunity for students to rate their abilities "before" relative to "after" the SRI training enables students to assess their skills and abilities reflectively and more accurately, based on a full understanding of the concepts.

In our study, science self-efficacy across all cohorts, measuring self-ability to perform tasks or skills, was moderately associated with academic self-concept, academic adjustment, belongingness, and the perception that the university contributes to the student's ability to conduct research (see Table 4). Academic self-concept, measuring self-belief in academic ability, and drive to achieve; academic adjustment measured with adjusting to the demands of college and developing close friendships with other students; belongingness measured as feeling a sense of belonging, being a part of the college and the campus community, and feeling valued; and a willingness to recommend the school, all align in this self-selected and ambitious student population. These findings resonate with findings by Estrada *et al.* (2011) on

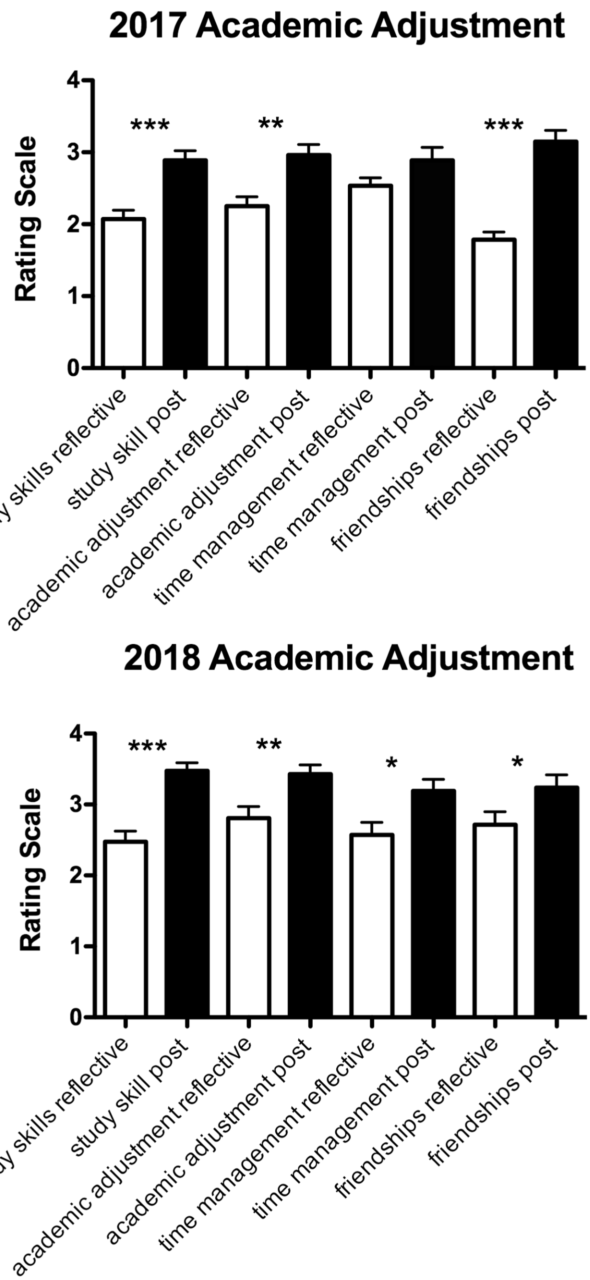

FIGURE 4. Gains for the Academic Adjustment construct questions for Cohorts 3 (2017) and 4 (2018). All questions show significant realistic gains in both cohorts. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

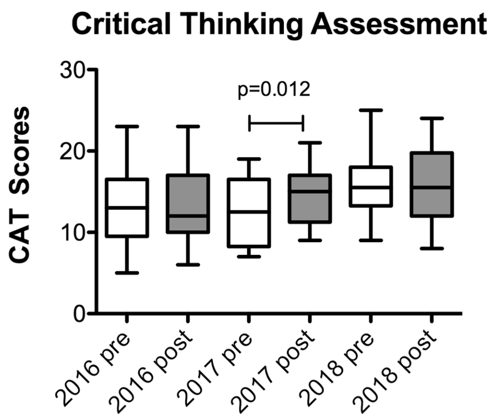

FIGURE 5. CAT tests show non-significant gains for most cohorts, with the exception of Cohort 3, which shows a significant gain.

the importance of a social system and connections for URMs in their integration into science.

Science identity in our study was not tested as robustly as science self-efficacy with using a validated science identity construct. Nevertheless, in this one cohort 4 (2018), the construct uncovered significant gains and realistic gains with large effect sizes in science identity in regard to "feeling of belonging to the science field and community, working on teams doing research, and thinking of themselves as a scientist" (see Table 3 and Figure 3). We surmise that measurement in earlier cohorts would have resulted in similar results.

Interestingly, science self-efficacy was not significantly correlated with science identity in our study. This would support the research on the tripartite integration model of social influence for STEM (Kelman, 2006), wherein science identity, as a distinct construct, accounts for persistence in STEM above science self-efficacy (Estrada *et al.*, 2011; Hernandez *et al.*, 2018a). However, interpretation of our data should be approached cautiously, because science identity as a construct did not receive a robust evaluation across all cohorts. With our STEM continuance and graduation rates, our results are aligned with other findings that a positive relationship exists between self-efficacy and pursuit of STEM careers (Estrada *et al.*, 2011).

The SRI's highly mentored, group-focused experiential training modules, incorporating entrepreneurial attributes, likely functioned to strengthen science identity. A review based on 60 published studies on undergraduate research experiences indicated that the students' interaction with professors helped with their self-perception as scientists and recognition of their building skills, while the greater time spent with graduate students assisted with technical skill building (Linn *et al.*, 2015). The interaction with five professors and five or more near-peer mentors in our program continually encouraged these types of activities and may have been a prominent factor in increased science identity. The SRI's unique experiential structure allowed the students to be researchers with self-derived research questions over multiple well-defined modules and to generate a student-derived research project. Others have made similar observations using an entrepreneurial training model (Robinson *et al.*, 2016).

The science identity construct for cohort 4 (2018) was moderately associated with academic self-concept. This study occurred at an historically black college or university (HBCU), and our findings may also parallel the Chang *et al.* (2016) conclusion that, for students with higher levels of domain association, lower levels of negative racial experiences are associated with better persistence. Finally, attending an HBCU may have also positively influenced the lack of a science identity gender effect. In previous studies, females were reported to perform lower than males (Lent *et al.*, 2005; Frantz *et al.*, 2017); this was not seen here, as the cohort percentage of females was more equivalent for cohort 4 (2018; see Table 1). Attending an HBCU thus may have had an impact. Comparisons with other institutional types in the future would provide more information.

Observed gains in academic adjustment items such as developing close friendships with other students, adjusting to college demands, developing effective study skills, and managing time effectively may be related to the program's emphasis on group discussions and working in groups. Scores were significantly improved with large effect sizes for cohorts 3 and 4, as seen in Figure 3 and Table 3, which is likely a consequence of continued improvements and fine-tuning of our curriculum over the course of the 4 cohorts. As mentioned, we found moderate correlations with science self-efficacy; however, correlations were also seen with a recognition that the university contributed to the students' ability to conduct research (see Table 4). The focus of the SRI on group processing of problems allowed the students to recognize and improve their own strengths, such as time management, and to explore other ways of handling problems through seeing and working with one another. This in turn may have resulted in participants seeing the university as assisting them with conducting research while increasing their feelings of belonging to the campus and community.

Because the SRI curriculum emphasizes problem solving, creative thinking, and effective communication, it comes as somewhat of a surprise that only one cohort showed significant gains in the CAT. Skills emphasized by the SRI are those also assessed in the CAT (Holmes *et al.*, 2015; Tennessee Tech University, 2020). Most likely, the duration of our SRI was too short. While some studies have found improvements using the CAT assessment over a semester-long course (Gasper and Gardner, 2013; Carson, 2015; Rowe *et al.*, 2015), most either did not see gains or showed mixed overall results (Frisch *et al.*, 2013; Cargas *et al.*, 2017; Perry *et al.*, 2018). Improvement in CAT critical-thinking skills even across a full semester is uncommon (Stein *et al.*, 2007; Rowe *et al.*, 2015) and is typically facilitated when interventions intentionally teach and provide practice in particular skill building (Niu *et al.*, 2013; Bensley and Spero, 2014; Abrami *et al.*, 2015; Tiruneh *et al.*, 2018; Halpern and Butler, 2019). While our program employed encouragement of critical thinking through its intense focus on research question development and experiential research activities, we did not focus intentionally on specific skills required in the CAT assessment.

Academic self-concept and belongingness items on our assessment tools are employed to measure broad terms relating to the larger university community. Academic self-concept included items asking comparisons of self to same-age others on "academic and mathematical ability", as well as "drive to achieve," and "intellectual self-confidence." These constructs would not be expected to change substantially during an 8-week research introduction program. Similarly, the items representing "belongingness" were related to the campus or college globally versus a specific program. Both sets of these questions were derived from the Diversity Program Consortium items, whose broader focus across vastly different campus types were not informed specifically by an HBCU campus population and institutional mission or the impact of a specific program or intervention.

Limitations

This study has several limitations. The ASCEND program invited applications from the student body and in subsequent years from surrounding community colleges for students attending or intending to attend the university. The requirements included a certain GPA (2.8), which is slightly higher than average in relevant majors at the institution. Other requirements included writing several prompted statements, along with obtaining two letters of recommendation. Recruiting freshmen with these characteristics and abilities meant the sample was subject to self-selection and skewed to higher-functioning and higher-performing students. Further, the recruitment pool and subsequent SRI participants included a preponderance of females, which was higher than the overall percentage of females at the university but roughly reflected the female to male ratio in the students' majors. This made it difficult to ascertain whether there might have been a male/female performance gap, as previously reported in the literature. Increased male participation would provide increased statistical power to afford the circumstances to show differences.

While we did make substantial curricular changes based on student feedback between the different cohorts, our interpretation that these improvements contributed to the growth in science identity and self-efficacy across cohorts cannot be clearly assessed. Each of the four cohorts included different individuals, such that the between-cohort analyses may reflect differences of the students more than perceived program refinements.

Future replications of our SRI training model will need to show whether the impact seen here on science self-efficacy and science identity in URM STEM and social/behavioral sciences students is transferable to other institutions, particularly non–minority serving institutions. This study was conducted at an HBCU in the mid-Atlantic region with greater than 90% of the student population being of African or African-American descent, and the majority of the instructors and near-peer mentors were from the same demographics as the students. As alluded to earlier, it is possible that the particular environment of an HBCU campus was instrumental to our success.

CONCLUSION

This 4-year study has provided proof of concept that our entrepreneurial research training program can be highly successful in increasing science self-efficacy, science identity, and retention in science majors for URMs. The ASCEND SRI is taught using an approach more akin to course-based undergraduate research than the typical SRI program (Auchincloss *et al.*, 2014; Shapiro *et al.*, 2015; Elgin *et al.*, 2016; Staub *et al.*, 2016; Frantz *et al.*, 2017). As detailed earlier, our data show robust increases in science self-efficacy, science identity, and academic self-adjustment, all of which are strong predictors of student success in college and subsequent retention into science careers and graduate training. Our observations concur with those Frantz *et al.* (2017) that an entrepreneurial, group-based training model can instill the same gains typically associated with an apprenticeship-type undergraduate research experience (Seymour *et al.*, 2004; Linn *et al.*, 2015; Shapiro *et al.*, 2015; Elgin *et al.*, 2016; Staub *et al.*, 2016; Frantz *et al.*, 2017). However, unlike the traditional apprenticeship model, our ASCEND training model maximizes student participation while decreasing impacts on mentor resources, particularly those in a mentor-to-mentee ratio. This approach makes the training model scalable for institutions with limited faculty-mentored research experiences.

Our specific curriculum is transferable to other institutions seeking to encourage greater access to research experiences and opportunities for URMs at colleges and universities, and we would welcome the communication of any institution with interest in doing so. Moreover, the interdisciplinary nature of our curriculum and focus on cross-discipline group interactions and communication builds essential skills for Team Science in research and entrepreneurial organizations alike (Hisrich, 1990; Heinzen *et al.*, 2018).

ACKNOWLEDGMENTS

We want to thank our program coordinator, Ms. Acquanette Pinchback, for her tireless efforts to make the SRI run smoothly each summer and for her unrivaled mentoring of our SRI students. We acknowledge funding through the NIH Diversity Program Consortium BUILD Award (UL1MD009605/RL5MD009590/TL4MD009635).

REFERENCES

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for teaching students to think critically: A meta-analysis. *Review of Educational Research*, *85*(2), 275–314.

Aronson, J., & Inzlicht, M. (2004). The ups and downs of attributional ambiguity: Stereotype vulnerability and the academic self-knowledge of African American college students. *Psychological Science*, *15*(12), 829–836.

Auchincloss, L. C., Laursen, S. L., Branchaw, J. L., Eagan, K., Graham, M., Hanauer, D. I., ... & Dolan, E. L. (2014). Assessment of course-based undergraduate research experiences: A meeting report. *CBE—Life Sciences Education*, *13*(1), 29–40. doi: 10.1187/cbe.14-01-0004

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191.

Bensley, D. A., & Spero, R. A. (2014). Improving critical thinking skills and metacognitive monitoring through direct infusion. *Thinking Skills and Creativity*, *12*(Suppl C), 55–68. doi: hTtps://doi.org/10.1016/j.tsc.2014.02.001

Bird, B. (1988). Implementing entrepreneurial ideas: The case for intention. *Academy of Management Review*, *13*(3), 442–453.

Brockhaus, R. H. (1982). The psychology of the entrepreneur. In *Encyclopedia of entrepreneurship* (pp. 39–57). Retrieved December 11, 2020, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1497760

Byars-Winston, A., & Rogers, J. G. (2019). Testing intersectionality of race/ethnicity× gender in a social–cognitive career theory model with science identity. *Journal of Counseling Psychology*, *66*(1), 30.

Byars-Winston, A., Rogers, J., Branchaw, J., Pribbenow, C., Hanke, R., & Pfund, C. (2016). New measures assessing predictors of academic persistence for historically underrepresented racial/ethnic undergraduates in science. *CBE—Life Sciences Education*, *15*(3), ar32. doi: 10.1187/cbe.16-01-0030

Cargas, S., Williams, S., & Rosenberg, M. (2017). An approach to teaching critical thinking across disciplines using performance tasks with a common rubric. *Thinking Skills and Creativity*, *26*, 24–37.

Carson, S. (2015). Targeting critical thinking skills in a first-year undergraduate research course. *Journal of Microbiology & Biology Education*, *16*(2), 148–156. doi: 10.1128/jmbe.v16i2.935

Chang, M. J., Eagan, M. K., Lin, M. H., & Hurtado, S. (2016). Considering the impact of racial stigmas and science identity: Persistence among biomedical and behavioral science aspirants. *Journal of Higher Education*, *82*(5), 564–596. doi: 10.1080/00221546.2011.11777218

Chemers, M. M., Hu, L. T., & Garcia, B. F. (2001). Academic self-efficacy and first year college student performance and adjustment. *Journal of Educational Psychology*, *93*(1), 55.

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., & Bearman, S. (2011). The role of efficacy and identity in science career commitment among underrepresented minority students. *Journal of Social Issues*, *67*(3), 469–491. doi: 10.1111/j.1540-4560.2011.01710.x

Claro, S., Paunesku, D., & Dweck, C. S. (2016). Growth mindset tempers the effects of poverty on academic achievement. *Proceedings of the National Academy of Sciences USA*, *113*(31), 8664–8668.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). New York, NY: Academic Press.

Diversity Program Consortium Coordination and Evaluation Center. (n.d.). *Hallmark details [Code book]*. Retrieved May 20, 2022, from http://ppsc.diversityprogramconsortium.org/ppsc/proposal-datasets-hallmarks/hallmark-details?hm_code=STU-3

Eagan, K., Stolzenberg, E. B., Zimmerman, H. B., Aragon, M. C., Whang Sayson, H., & Rios-Aguilar, C. (2017). *The American freshman: National norms fall 2016*. Los Angeles: Higher Education Research Institute, UCLA.

Elgin, S. C. R., Bangera, G., Decatur, S. M., Dolan, E. L., Guertin, L., Newstetter, W. C., ... & Labov, J. B. (2016). Insights from a convocation: Integrating discovery-based research into the undergraduate curriculum. *CBE—Life Sciences Education*, *15*(2), fe2. doi: 10.1187/cbe.16-03-0118

Estrada, M., Woodcock, A., Hernandez, P. R., & Schultz, P. W. (2011). Toward a model of social influence that explains minority student integration into the scientific community. *Journal of Educational Psychology*, *103*(1), 206–222. doi: 10.1037/a0020743

Fiegener, M. K., & Proudfoot, S. L. (2013). *Baccalaureate origins of US-trained S&E doctorate recipients*. Arlington, VA: National Science Foundation.

Field, A. (2013). *Discovering statistics using IBM-SPSS statistics* (4th ed.). Los Angeles: Sage.

Frantz, K. J., Demetrikopoulos, M. K., Britner, S. L., Carruth, L. L., Williams, B. A., Pecore, J. L., ... & Goode, C. T. (2017). A comparison of internal dispositions and career trajectories after collaborative versus apprenticed research experiences for undergraduates. *CBE—Life Sciences Education*, *16*(1), ar1. doi: 10.1187/cbe.16-06-0206

Freeman, R. B., & Huang, W. (2014). Collaboration: Strength in diversity. *Nature*, *513*(7518), 305–305. doi: 10.1038/513305a

Frisch, J. K., Jackson, P. C., & Murray, M. C. (2013). WikiED: Using Web 2.0 tools to teach content and critical thinking. *Journal of College Science Teaching*, *43*(1), 70–80.

Gasper, B. J., & Gardner, S. M. (2013). Engaging students in authentic microbiology research in an introductory biology laboratory course is correlated with gains in student understanding of the nature of authentic research and critical thinking. *Journal of Microbiology & Biology Education*, *14*(1), 25–34. doi: 10.1128/jmbe.v14i1.460

Ghosh, N. B., & Raharam, G. (2015). Developing emotional intelligence for entrepreneurs: The role of entrepreneurship development programs. *South Asian Journal of Management*, *22*(4), 85–100.

Gibbs, K. D., Jr., & Marsteller, P. (2016). Broadening participation in the life sciences: Current landscape and future directions. *CBE—Life Sciences Education*, *15*(3)doi: 10.1187/cbe.16-06-0198

Halpern, D. F., & Butler, H. A. (2019). Teaching critical thinking as if our future depends on it, because it does. In Dunlosky J., & Rawson K. A. (Eds.), *The Cambridge handbook of cognition and education* (pp. 51–66). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/9781108235631.004

Heinzen, M., Cacciatori, E., Zoller, F. A., & Boutellier, R. (2018). Who talks to whom about what? How interdisciplinary communication and knowledge of expertise distribution improve in integrated R&D labs. *Ergonomics*, *61*(8), 1139–1153.

Hernandez, P. R., Hopkins, P. D., Masters, K., Holland, L., Mei, B. M., Richards-Babb, M., ... & Shook, N. J. (2018a). Student integration into STEM careers and culture: A longitudinal examination of summer faculty mentors and project ownership. *CBE—Life Sciences Education*, *17*(3), ar50.

Hernandez, P. R., Woodcock, A., Estrada, M., & Schultz, P. W. (2018b). Undergraduate research experiences broaden diversity in the scientific workforce. *BioScience*, *68*(3), 204–211. doi: 10.1093/biosci/bix163

Herring, C. (2009). Does diversity pay? Race, gender, and the business case for diversity. *American Sociological Review*, *74*(2), 208–224.

Hisrich, R. D. (1990). Entrepreneurship/intrapreneurship. *American Psychologist*, *45*(2), 209.

Holmes, N. G., Wieman, C. E., & Bonn, D. A. (2015). Teaching critical thinking. *Proceedings of the National Academy of Sciences USA*, *112*(36), 11199–11204. doi: 10.1073/pnas.1505329112

Hunt, V., Layton, D., & Prince, S. (2015, February 2). Diversity matters. *McKinsey & Company*, *1*(1), 15–29. https://www.insurance.ca.gov/diversity/41-ISDGBD/GBDExternal/upload/McKinseyDivmatters-201501.pdf

Jackson, A. D., Boorman, E. P., Kamangar, F., & Hohmann, C. F. (2018). Student affect during an HBCU summer research program. *Understanding Interventions Journal*, *9*(2). https://www.understandinginterventionsjournal.org/article/6351

Jeffe, D. B., Yan, Y., & Andriole, D. A. (2012). Do research activities during college, medical school, and residency mediate racial/ethnic disparities in full-time faculty appointments at US Medical schools? *Academic Medicine*, *87*(11), 1582.

Kamangar, F., Silver, G., Hohmann, C., Hughes-Darden, C., Turner-Musa, J., Haines, R. T., ... & Sheikhattari, P. (2017). An entrepreneurial training model to enhance undergraduate training in biomedical research. *BMC Proceedings*, *11*(Suppl 12), 18. doi: 10.1186/s12919-017-0091-8

Kamangar, F., Silver, G., Hohmann, C., Mehravaran, S., & Sheikhattari, P. (2019). Empowering undergraduate students to lead research: The ASCEND program at Morgan State University. In Wilson-Kennedy Z. S., Byrd G. S., Kennedy E., & Frierson H. T. (Eds.), *Broadening participation in STEM: Effective methods, practices, and programs* (pp. 35–53). Bingly, UK: Emerald Publishing Limited.

Kelman, H. C. (2006). Interests, relationships, identities: Three central issues for individuals and groups in negotiating their social environment. *Annual Review of Psychology*, *57*, 1–26.

Lent, R. W., Brown, S. D., Schmidt, J., Brenner, B., Lyons, H., & Treistman, D. (2003). Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive models. *Journal of Counseling Psychology*, *50*(4), 458–465. https://doi.org/10.1037/0022-0167.50.4.458

Lent, R. W., Brown, S. D., Sheu, H.-B., Schmidt, J., Brenner, B. R., Gloster, C. S., ... & Treistman, D. (2005). Social cognitive predictors of academic interests and goals in engineering: Utility for women and students at historically black universities. *Journal of Counseling Psychology*, *52*(1), 84.

Lindsey, B. A., & Nagel, M. L. (2015). Do students know what they know? Exploring the accuracy of students' self-assessments. *Physical Review Special Topics—Physics Education Research*, *11*(2), 020103.

Linn, M. C., Palmer, E., Baranger, A., Gerard, E., & Stone, E. (2015). Education. Undergraduate research experiences: Impacts and opportunities. *Science*, *347*(6222), 1261757. doi: 10.1126/science.1261757

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE—Life Sciences Education*, *6*(4), 297–306. doi: 10.1187/cbe.07-06-0039

Lujan, H. L., & DiCarlo, S. E. (2017). A personal connection: Promoting positive attitudes towards teaching and learning. *Anatomical Sciences Education*, *10*(5), 503–507.

McCreath, H. E., Norris, K. C., Calder⊠n, N. E., Purnell, D. L., Maccalla, N. M., & Seeman, T. E. (2017, December). Evaluating efforts to diversify the biomedical workforce: The role and function of the Coordination and Evaluation Center of the Diversity Program Consortium. In *BMC Proceedings*, *11*(12), 15–26).

Merolla, D. M., & Serpe, R. T. (2013). STEM enrichment programs and graduate school matriculation: The role of science identity salience. *Social Psychology of Education*, *16*(4), 575–597. doi: 10.1007/s11218-013-9233-7

Meyers, F. J., Mathur, A., Fuhrmann, C. N., O'Brien, T. C., Wefes, I., Labosky, P. A., ... & Chalkley, R. (2016). The origin and implementation of the Broadening Experiences in Scientific Training programs: An NIH common fund initiative. *FASEB Journal*, *30*(2), 507–514. doi: 10.1096/fj.15-276139

Meyers, L. C., Brown, A. M., Moneta-Koehler, L., & Chalkley, R. (2018). Survey of checkpoints along the pathway to diverse biomedical research faculty. *PLoS ONE*, *13*(1), e0190606. doi: 10.1371/journal.pone.0190606

Nagda, B. A., Gregerman, S. R., Jonides, J., von Hippel, W., & Lerner, J. S. (1998). Undergraduate student-faculty research partnerships affect student retention. *Review of Higher Education*, *22*(1), 55–72. doi: 10.1353/rhe.1998.0016

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2011). *Expanding underrepresented minority participation: America's science and technology talent at the crossroads*. Washington, DC: National Academies Press. https://doi.org/10.17226/12984

National Center for Science and Engineering Statistics. (2020). *Doctorate recipients from U.S. universities: 2019 (NSF 21-308)*. Alexandria, VA: National Science Foundation. Retrieved November 3, 2021, from https://ncses.nsf.gov/pubs/nsf21308

National Institutes of Health. (2019). *Hallmarks of success*. Retrieved March 20, 2022, from www.nigms.nih.gov/training/dpc/Pages/success.aspx

Niu, L., Behar-Horenstein, L. S., & Garvan, C. W. (2013). Do instructional interventions influence college students' critical thinking skills? A meta-analysis. *Educational Research Review*, *9*(Suppl C), 114–128. doi: https://doi.org/10.1016/j.edurev.2012.12.002

Perry, D. K., Paulsen, T. H., & Retallick, M. S. (2018). Differences in critical thinking ability according to college entry pathway. *NACTA Journal*, *62*(2), 115.

President's Council of Advisors on Science and Technology. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. Washington, DC: U.S. Government Office of Science and Technology.

Robbins, S. B., Lauver, K., Le, H., Davis, D., Langley, R., & Carlstrom, A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. *Psychological Bulletin*, *130*(2), 261–288. https://doi.org/10.1037/0033-2909.130.2.261

Robinson, S., Matlay, P. H., Neergaard, H., Tanggaard, L., & Krueger, N. F. (2016). New horizons in entrepreneurship education: From teacher-led to student-centered learning. *Education + Training*, *58*(7/8), 661–683. doi: 10.1108/et-03-2016-0048

Rosique-Blasco, M., Harry Matlay, P., Madrid-Guijarro, A., & García-Pérez-de-Lema, D. (2016). Entrepreneurial skills and socio-cultural factors. *Education + Training*, *58*(7/8), 815–831. doi: 10.1108/et-06-2015-0054

Rowe, M. P., Gillespie, B. M., Harris, K. R., Koether, S. D., Shannon, L.-J. Y., & Rose, L. A. (2015). Redesigning a general education science course to promote critical thinking. *CBE—Life Sciences Education*, *14*(3). doi: 10.1187/cbe.15-02-0032

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. (2011). Benefits of undergraduate research experiences. *Science*, *316*(5824), 1140384. doi: 10.1126/science.1140384

Schultz, P. W., Hernandez, P. R., Woodcock, A., Estrada, M., Chance, R. C., Aguilar, M., & Serpe, R. T. (2011). Patching the pipeline: Reducing educational disparities in the sciences through minority training programs. *Educational Evaluation and Policy Analysis*, *33*(1), 95–114.

Serra, M. J., & DeMarree, K. G. (2016). Unskilled and unaware in the classroom: College students' desired grades predict their biased grade predictions. *Memory & Cognition*, *44*(7), 1127–1137.

Seymour, E., Hunter, A. B., Laursen, S. L., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education*, *88*(4), 493–534.

Shapiro, C., Moberg-Parker, J., Toma, S., Ayon, C., Zimmerman, H., Roth-Johnson, E. A., ... & Sanders, E. R. (2015). Comparing the Impact of Course-Based and Apprentice-Based Research Experiences in a Life Science Laboratory Curriculum. *Journal of Microbiology and Biology Education*, *16*(2), 186–197. doi: 10.1128/jmbe.v16i2.1045

Siegel, S., & Castellan, N. J., Jr. (1988). *Nonpara metric statistics: For the behavioral sciences* (2nd ed.). New York, NY: McGraw-Hill.

Spitzer, B., & Aronson, J. (2015). Minding and mending the gap: Social psychological interventions to reduce educational disparities. *British Journal of Educational Psychology*, *85*(1), 1–18.

Staub, N. L., Blumer, L. S., Beck, C. W., Delasalle, V. A., Griffin, G. D., Merritt, R. B., ... & Mader, C. M. (2016). Course-based science research promotes learning in diverse students at diverse institutions. *CUR Quarterly*, *38*(2), 36–46.

Stein, B., Haynes, A., & Redding, M. (2016, April). National dissemination of the CAT instrument: Lessons learned and implications. In *Proceedings of the AAAS/NSF envisioning the future of undergraduate STEM education: Research and practice symposium, Washington, DC*.

Stein, B., Haynes, A., Redding, M., Ennis, T., & Cecil, M. (2007). Assessing critical thinking in STEM and beyond. In *Innovations in e-learning, instruction technology, assessment, and engineering education* (pp. 79–82). Middlesex St, Lowell, MA: Springer.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5 ed). Boston, MA: Pearson Education.

Tennessee Tech University. (2020). *About the CAT*. Retrieved November 11, 2020, from www.tntech.edu/cat/about.php

Thoman, D. B., Smith, J. L., Brown, E. R., Chase, J., & Lee, J. Y. K. (2013). Beyond performance: A motivational experiences model of stereotype threat. *Educational Psychology Review*, *25*(2), 211–243. Retrieved from www.jstor.org/stable/43549773

Tibbetts, Y., Harackiewicz, J. M., Priniski, S. J., & Canning, E. A. (2016). Broadening participation in the life sciences with social–psychological interventions. *CBE—Life Sciences Education*, *15*(3), es4.

Tiruneh, D. T., De Cock, M., & Elen, J. (2018). Designing learning environments for critical thinking: Examining effective instructional approaches. *International Journal of Science and Mathematics Education*, *16*(6), 1065–1089. doi: 10.1007/s10763-017-9829-z

Trujillo, G., & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE—Life Sciences Education*, *13*(1), 6–15.

Valantine, H. A., & Collins, F. S. (2015). National Institutes of Health addresses the science of diversity. *Proceedings of the National Academy of Sciences USA*, *112*(40), 12240–12242. doi: 10.1073/pnas.1515612112

Valantine, H. A., Lund, P. K., & Gammie, A. E. (2016). From the NIH: A systems approach to increasing the diversity of the biomedical research workforce. *CBE—Life Sciences Education*, *15*(3), fe4. doi: 10.1187/cbe.16-03-0138

Wei, C. A., & Woodin, T. (2011). Undergraduate research experiences in biology: Alternatives to the apprenticeship model. *CBE—Life Sciences Education*, *10*(2), 123–131.