Puerto Rican Students Rising in STEM: Findings from a Multicampus Collaborative CURE Program to Promote Student Success

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ABSTRACT
Although Hispanic population is growing rapidly, Latino students earn fewer STEM degrees than their peers. Therefore, it is mandatory to implement strategies that improve STEM retention and graduation rates for Hispanic students. There is little research about the ways in which multicampus collaborative CUREs combined with additional academic support, affect low-income, Hispanic students and none that focus solely on Puerto Rican students in STEM. Puerto Rico (PR) has a 99% Hispanic population; thus, it is imperative to include PR in education research literature. This study sought to examine the impacts of the Research for Improved Student Experiences (RISE) in STEM program at two campuses of the Inter American University of Puerto Rico. The program included multicampus collaborative CUREs, academic advising, and peer mentoring using quasi-experimental design. Impact assessment included psychosocial metrics such as self-efficacy, science identity and sense of belonging in a pre/posttest design. These findings were triangulated with the differences between treatment and control for retention, pass rate, and course grades. The findings revealed statistically significant improvements on all metrics. This study's findings support multicampus collaborative CUREs, academic advising, and peer mentoring as useful and effective strategies for improving outcomes for low-income Hispanic students in Puerto Rico.

INTRODUCTION
The development of a diverse technical workforce is necessary to maximize our competitiveness in the global economy. According to data from the U.S. Bureau of Labor Statistics (BLS, 2022), it is projected that STEM occupations will increase at a faster rate than non-STEM occupations for the foreseeable future. To meet the increasing demand in STEM fields, a much larger cross-section of the U.S. population must be prepared to maintain the momentum of discovery and innovation that will further the nation's economic prosperity. The Hispanic population is the fastest growing demographic in the United States accounting for 19.1% of the U.S. population (U.S. Census Bureau, 2022). However, only 15% of Hispanic students received bachelor's degrees in STEM fields (Snyder *et al*., 2016). Although the number of Latino students enrolling in STEM careers has increased in recent years, only 16% of Hispanic students that were enrolled in STEM majors in 2003–04 academic year completed a STEM degree by 2009 (Crisp and Nora, 2012; Higher Education Research Institute, 2010). Therefore, it is necessary to implement strategies that adequately develop skills that are imperative for jobs in the 21st century and lead to increased retention and graduation rates of Hispanic students in STEM disciplines.

Course-based Undergraduate Research Experiences (CUREs), defined as learning experiences in which students make discoveries that are relevant to others outside the learning environment have been increasingly utilized as a form of high-impact

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teaching practice that is meant to improve scientific skills (Jordan *et al.*, 2014; Bell *et al.*, 2017; Gin *et al*., 2018; Ing *et al*., 2021; Buchanan and Fisher, 2022). Improvements in scientific skills can positively impact the ways in which students see themselves and their abilities in STEM. These perceptions that students have about their own abilities in STEM are defined as psychosocial constructs (such as self-efficacy, science identity, and sense of belonging) which are positively associated with academic performance, retention, and persistence in STEM, especially for underrepresented minority students (Shaffer *et al.*, 2010; Harrison *et al*., 2011; Auchincloss *et al.*, 2014; Jordan *et al.*, 2014; Dolan, 2016; Delventhal and Steinhauer, 2020).

Additional activities including collaborative research, peer mentoring, and academic advising have also been reported to be particularly beneficial for students from underrepresented minority groups due in part to the ways in which these activities influence changes in the psychosocial constructs of interest in this study (self-efficacy, science identity, and sense of belonging) (Mavrinac, 2005; Murakami and Núñez, 2014; Thomas *et al*., 2015; Toven-Lindsey *et al*., 2015; Mirzaei *et al*., 2019). According to Woodzicka *et al.* (2015), through collaborative undergraduate research between teams at different institutions, using technological tools, students gained a fuller appreciation of the research process and developed collaborative skills that are not only becoming increasingly important in the professional world and research setting, but also are linked to improved self-efficacy (Woodzicka, 2015; Du *et al.*, 2019). Moreover, academic advisement and peer mentoring are recognized as an important mechanism to increase student success, retention, and graduation (Anderson, 2014). Successful peer-mentoring relationships foster higher academic achievement and student retention because they also enhance general self-confidence (self-efficacy), personal growth, and self-empowerment. Additionally, peer mentoring has been linked to improved sense of belonging because it gives students an opportunity to feel connection with other students in similar circumstances. Peer mentoring is particularly important for Hispanic students and improves overall college experiences for both the mentor and mentee (Mavrinac, 2005; Murakami and Núñez, 2014; Thomas *et al.*, 2015). Access to academic advising is important for student success in college but is even more critical for historically underrepresented students (such as low-income, Hispanic students) especially in STEM (Toven-Lindsey *et al.*, 2015). It benefits students academically by supporting the design and execution of their path to graduation and socially by improving students' performance and connection to the institution which in turn can enhance self-efficacy and sense of belonging (Hawthorne and Cooper, 2022).

In this study, a multicampus collaborative CURE model combined with academic advisement and peer mentoring was designed and implemented as the RISE in STEM program. The program impacted introductory chemistry, physics, and biology laboratory courses at two primarily undergraduate Hispanic serving institutions (The Ponce and Bayamon campuses of the Inter American University of Puerto Rico). This program relies on the theory of change that suggests that implementation of high-impact pedagogical strategies such as CURE, peer mentoring, academic advisement, and collaborative learning leads to improvements on measurable psychosocial constructs that are related to improved outcomes for underrepresented minorities in STEM (Milner *et al*., 2014; Ballen *et al*., 2017; Cheryan *et al*., 2017; Winter and Haynes, 2019). The theoretical framework provides more details about the psychosocial constructs and the way they inform the theory of change for this study.

The study sought to answer the following research questions:

- How do RISE in STEM program participants' science identity, self-efficacy in STEM, and sense of belonging change over the course of a semester?
- How does participation in the RISE in STEM program impact low-income Hispanic students' performance and retention when compared with nonparticipating students?

Although there are several studies reporting the positive benefits of engaging undergraduate students in collaborative research, the evaluation of the impact of CUREs in a multicampus collaborative model combined with support activities at a primarily undergraduate Hispanic serving institution is absent in the current literature. Therefore, this study provides novel evidence about how a multicampus collaborative model in CUREs combined with academic advisement and peer mentoring can contribute to improved student perceptions and performance in STEM.

Theoretical Framework

Education research literature supports the use of interventions that seek to improve student outcomes by improving student perceptions (attitudes) on several key psychosocial metrics. The metrics used to support the design of this study are science (STEM) identity, sense of belonging, and self-efficacy in STEM. For the purposes of this study, science identity is used and measured according to McDonald *et al.* (2019) where it is described as the way in which a person sees themselves in relationship to science or STEM. McDonald *et al.* (2019) established that when science identity is improved, there is also often an associated improvement in outcomes such as grades, retention in STEM or in college, and even graduation because when students see themselves as "scientists" they exhibit more successful outcomes in the STEM pursuits.

Similarly, self-efficacy, as it pertains to STEM, is often used and associated with improved student outcomes (Rittmayer and Beier, 2009). For this study, self-efficacy is defined as the student's perception of their own confidence to perform a certain STEM activity. Measuring self-efficacy in STEM allows for research to examine changes in student's confidence in STEM surrounding a given educational intervention. Positive changes in student self-efficacy in STEM have been associated with improved student outcomes such as retention, grades, and graduation because when students feel confident in their own abilities, they often also perform with more success (Rittmayer and Beier, 2009; Carpi *et al*., 2017). When Bandura (1977) first introduced self-efficacy theory, it was identified as a way to predict behavior based on confidence level and this is the same way in which it was used in this study where changes in confidence are measured as associated with improved outcomes.

Research that targets populations of students that have been historically underserved or disadvantaged in any way often uses sense of belonging as a way to measure students' experiences. Sense of belonging is defined as one's own perception of fitting in and/or belonging to a group (Hagerty and Patusky, 1995; Hoffman *et al*., 2002; Hausmann *et al*., 2007). Sense of belonging is particularly important in groups of individuals that are likely to feel excluded such as first-generation students at college or underrepresented students in STEM fields. Therefore, improving a student's sense of "fitting in" or belonging (in college or in STEM) is likely to increase their desire to stay in college or in STEM and therefore likely to increase their retention in college or in STEM.

In seeking to improve these psychosocial constructs, the RISE in STEM program is comprised of four key interventions; academic advisement, collaborative learning, peer mentoring, and CURE-treated courses that have been linked to student success. The activities in this program have been shown to increase student engagement, performance, and perceptions (sense of belonging, self-efficacy, and science identity) that are linked to retention and persistence in STEM (Shaffer *et al.*, 2010; Harrison *et al.*, 2011; Auchincloss *et al.*, 2014; Jordan *et al.*, 2014; Dolan, 2016; Delventhal and Steinhauer, 2020). The RISE in STEM program framework is further supported by the findings of the University of California Los Angeles (UCLA), Program for Excellence in Education and Research in the Sciences (PEERS) program, which was very successful at improving retention and graduation in STEM for underrepresented minorities (URM) (Toven-Lindsey *et al.*, 2015). The PEERS model used research based on students' first-year experiences (Tinto, 1999) as a basis to apply early interventions to improve outcomes for the most disadvantaged students in STEM. The interventions used by the PEERS model included academic counseling/advisement, collaborative learning, and research activities. These interventions supported the improvement of perceptions in self-efficacy, sense of belonging, science identity, and desire to persist in STEM. Participation in the PEERS program was found to be predictive of taking a higher number of science courses in the first two years of college, earning higher grades in gateway/bottleneck STEM courses, increased motivation to persist in STEM, increased science identity, improved sense of community (sense of belonging), and improved confidence in STEM (self-efficacy), leading Toven-Lindsey *et al*. (2015) to conclude that "PEERS serves as an excellent model for universities interested in and committed to improving persistence of underrepresented science majors." Therefore, this study is guided by the design used by the PEERS program as evidentiary and applied the same model to the problem of low-retention and graduation in STEM for low-income/disadvantaged Hispanic students, with similar results.

METHODS

This study received Institutional Review Board (IRB) approval (IRB review number: 1772502-1).

Study Context

The Characteristics of the Campuses. The Inter American University of Puerto Rico Ponce (IAUPR-PC) and Bayamon Campuses (IAUPR-BC) are two primarily undergraduate Hispanic Serving Institutions (99% of their population is Hispanic) that serve the academic needs of disadvantaged minority students from the south and north-central metropolitan area of Puerto Rico. From 2015 to 2018, the average STEM freshman to sophomore retention rates for IAUPR-PC and IAUPR-BC were 59 and 63%, respectively (IAUPR Research, Assessment and Planning Office). For the same time period (2015–18) the average STEM sophomore to junior retention rates were even lower, 40 and 45%, respectively. The average 6-year graduation rates from 2015 to 2018 for the STEM programs at IAUPR-PC and IAUPR-BC were 14%; compared with the nationwide graduation rate for Hispanic students in STEM of 43%, the graduation rate for both campuses is below the national standard (Riegle-Crumb *et al*., 2019).

The RISE in STEM Program: A multicampus collaborative CURE model combined with academic advisement and peer mentoring

In the collaborative CURE model students worked in a multicampus research project with faculty and peer leaders at each campus. This model required students enrolled in general physics or biology laboratory courses at IAUPR-BC to collaborate with students enrolled in general chemistry laboratory courses at IAUPR-PC. In the Spring semester of 2022, the collaborative model was implemented in one laboratory section of general chemistry (IAUPR-PC) and one laboratory section of general physics (IAUPR-BC). In the fall semester of 2022, the model was implemented in four laboratory sections (one laboratory section of general biology [IAUPR-BC] collaborated with one laboratory section of general chemistry [IAUPR-PC], and one laboratory section of general physics [IAUPR-BC] collaborated with one laboratory section of general chemistry [IAUPR-PC]). These collaborative laboratory sections were scheduled at the same time and day at both campuses to facilitate the collaboration process by allowing students, peer leaders, and CURE-trained lab instructors (faculty that participated in the training workshops related to CUREs development and implementation) from both campuses to interact virtually during the laboratory sessions.

The collaborative model included academic support such as peer mentoring and faculty advising (Szteinberg, 2012; Weaver *et al*., 2015) that has been shown to increase student engagement and retention. The incorporation of peer leaders into CUREs has demonstrated a positive impact on the participating students by improving their experiences within a research group community (Szteinberg and Weaver, 2013). For each lab section in the Spring semester of 2022, peer leaders were recruited by contacting students who successfully completed the corresponding course (biology, chemistry, or physics) and had previous research experience (participation in research-based courses, summer research or research with a faculty member). In the Fall Semester of 2022, peer leaders were students who previously participated in the RISE in STEM program. Peer leaders attended the three-hour lab session every week (week 1–15) and met weekly (from week 6 to week 15) with their mentees for one hour in an assigned classroom or remotely to provide guidance in the topics discussed in the laboratory course and the research process. Additionally, peer leaders offered workshops related to keeping a lab notebook, ethics in research, how to write an abstract and how to make a good presentation in an oral or poster format that were previously designed by the RISE in STEM program. Peer leaders met weekly with CURE-trained lab instructors to discuss the weekly topics (concepts and problems) to be covered in the discussion group. In addition, STEM faculty across both campuses participated as academic advisors

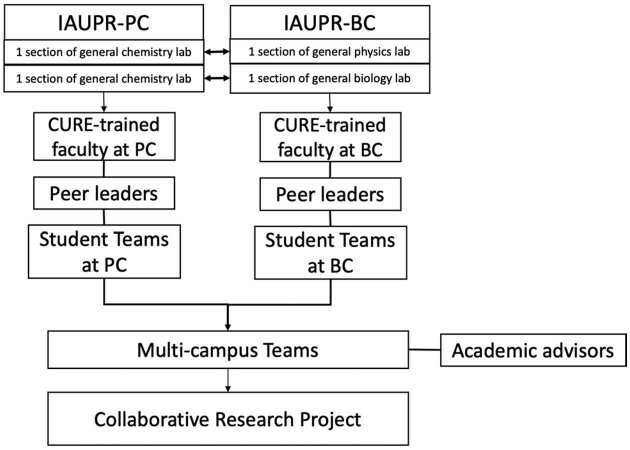

FIGURE 1. The RISE in STEM Program: A multicampus, collaborative CURE model combined with academic advisement and peer mentoring. Peer leaders attended the 3-h lab sections every week (1–15) and met weekly (week 6–15) with their mentees for 1 h in an assigned classroom or remotely. Academic advisors held six remote meetings with their multicampus groups during weeks: 5, 7, 9, 11, 13, and 15.

for students. These advisors counseled the multicampus student teams throughout each term, guiding them on course-load, planning for graduation, applications for external summer research experiences and offering support for pursuing a degree in STEM. Six remote meetings were held during each academic term. Group Mentoring was used for this activity, where, instead of attending students separately, one faculty works with them in teams on a common project and goal. Group Mentoring effectively strengthens the relationships between all participants involved and encourages a natural exchange of information in a team-based environment (Ward *et al*., 2014).

The first step for the implementation of the RISE in STEM program was the formation of the teams by dividing each laboratory section into groups of two or three students. A peer-leader was assigned to teams from their home campus (one peer leader was matched with three or four teams). Then, each IAUPR-BC team established a collaboration with an IAUPR-PC team. Therefore, a network of four or five students and two peer leaders worked together on a research question or problem under the guidance and supervision of CURE-trained faculty laboratory instructors (one faculty member from each campus). An academic advisor was assigned to each multicampus team to support them as they worked on their collaborative research projects and through their pursuit of a degree (Figure 1). The teams from both campuses met personally two times during the semester so that they could interact face to face (IAUPR-BC and IAUPR-PC are less than 2 h away from each other) and most of the collaboration was accomplished electronically through WhatsApp, email, Blackboard Collaborate and Microsoft Teams. It has been reported that the use of these technological tools is effective for collaborative undergraduate research (Woodzicka *et al.*, 2015).

Materials

Students conducted authentic research using two collaborative modules written by the RISE in STEM Program. The collaborative module used for the biology (IAUPR-BC) and chemistry (IAUPR-PC) laboratory sections was related to the study of the biological activity of secondary compounds found in local plants. Students chose a plant for their experiment after a literature search or from a list provided by the instructor. Then, students enrolled in the chemistry laboratory extracted the secondary metabolites and evaluated their compatibility with alginate hydrogels. Students enrolled in the biology laboratory evaluated how these metabolites impacted the growth of bacteria or fungus. The collaborative module used for the physics (IAUPR-BC) and chemistry (IAUPR-PC) laboratory sections involved the fabrication and characterization of enzymatically-crosslinked gelatin hydrogels containing nanostructures for wound healing. After searching in the literature, students decided the type of nanostructures to be incorporated into the hydrogels. Some multicampus teams decided to incorporate additional components such as aloe vera and curcumin. Students enrolled in the physics laboratory synthesized and characterized the nanostructures while students enrolled in the chemistry laboratory fabricated and characterized the hydrogels containing the nanostructures.

The first 5–6 wk of the semester were devoted to skill-building laboratories (traditional laboratory work) and the remaining weeks were devoted to the multicampus research project. This schedule has demonstrated to be effective in impacting student performance and perceptions, as demonstrated by the Center for Authentic Science Practice in Education-CASPiE (Scantlebury *et al*., 2011; Szteinberg and Weaver, 2013). The collaborative modules included three weeks for research techniques where students enrolled in each laboratory section were trained to successfully complete their collaborative projects, followed by a laboratory period devoted to experimental design (the multi-campus teams met virtually to discuss the research question or hypothesis and the experiments to test it). After these weeks, students had two or three additional weeks to perform their experiments followed by two or three more weeks for data analysis and poster preparation (Table 1). At the end of the semester students presented their findings at a mini-symposium organized by the RISE in STEM program.

Participants

The participants from this study were students who took the general chemistry laboratory (IAUPR-PC) and general physics laboratory (IAUPR-BC) in the Spring and Fall semesters of 2022, and general biology laboratory (IAUPR-BC) in the Fall semester of 2022. These sections usually have a student

TABLE 1. Schedule used for the RISE in STEM Program[a]

Week	General chemistry laboratory	General physics or biology laboratory
1–5	Traditional lab	Traditional lab
6–8	Research techniques	Research techniques
9	Research design	
10–12	Multicampus research project	
13–15	Data analysis and poster preparation	

[a]Peer leaders attended the 3-h lab session every week (1–15) and met weekly (week 6–15) with their mentees for 1 h in an assigned classroom or remotely. Academic advisors held six remote meetings with their multicampus groups during weeks: 5, 7, 9, 11, 13, and 15.

TABLE 2. Demographics for participant and nonparticipant students

	Treatment group demographics		Control group demographics	
	N	Percentage	N	Percentage
Male	20	26%	47	38%
Female	58	74%	78	62%
Hispanic	78	100%	123	98%
Non-Hispanic	0	0.0%	2	2%
Low-income	65	83%	96	77%
Not low-income	13	17%	29	23%
First generation	17	22%	23	18%
Not first generation	61	78%	102	82%

enrollment between 12 and 20 students per semester. Demographic details about the RISE in STEM program participants ($n = 78$) and students from the control group sections ($n = 125$) are included in Table 2. These data reflect that the majority of the student population supported by the RISE in STEM program was female, Hispanic, and low income (defined here as Pell-eligible based on admissions data).

Treatment Assignment

For the chemistry laboratory courses at Ponce campus, students self-selected into the lecture/lab course that they preferred with no prior knowledge of the treatment status of the course nor of the research project. During the second week of class, the students were informed of the research project and their status as either treatment or control. Consent/assent procedures as established by the IRB at the Inter American University were administered and all students from the treatment and control groups were consented/assented into the project. For the physics laboratory courses at Bayamon Campus, self-selection into treatment/control groups was not possible because the enrollment was low. There was only one section of the lecture offered, as supported by the enrollment numbers. Therefore, students were randomly assigned to treatment/control laboratory sections for Physics, due to enrollment. However, the Biology lab course at Bayamon, which did not have low enrollment, was assigned to treatment/control in the same manner as the Physics, due to administrative preferences of that campus. Students in the traditional laboratory course performed experiments described in their laboratory manual as usual. Only CURE-trained faculty taught treated course sections. Different, non-CURE-trained faculty taught the nontreatment laboratory course sections (control group). The lecture portion of the courses was the same for the control and experimental group and were taught by either the CURE-trained professor or another professor.

Data collection and analysis

Student perceptions. At the beginning of the semester (week three, before treatment) and at the end of the semester (week 15, after treatment), pre- and postsurveys were administered to students enrolled in all of the treated laboratory sections offered at the Bayamon and Ponce campuses for the Spring and Fall 2022 terms to measure change on key psychosocial metrics (sense of belonging, science identity, and self-efficacy) over time. These data were quantitative to allow for statistical analyses and used Likert-type scales to measure perceptions.

The questionnaire used in the pre- and postsurveys included a single-item pictorial response to measure the construct of science identity (McDonald *et al.*, 2019), 17 items to measure self-efficacy related to skills that students gained in the laboratory using a confidence scale (0 = not at all confident and 10 = completely confident), and 9 items to measure sense of belonging using an agreement scale (0 = do not agree at all and 10 = completely agree). For analysis, the self-efficacy and sense of belonging scales were converted to 1 to 11.

The single-item pictorial response used to measure the construct of science identity is based on the measure of interpersonal closeness developed by Aron *et al*. (1992), and provides information related to the current perceived overlap of students with a STEM professional. Additionally, it allows to track the progress of students' science identity over time. For analysis, the responses to this item were converted to numeric scores where 1 = the first image with no overlap, continuing counting upward as overlap increases so that 7 = the last image with almost full overlap. The item is included in Figure 2 as it appeared in the survey for ease of interpretation of the findings.

The sense of belonging items was modified by the program's external evaluator based on similar items designed and validated by Winter and Haynes (2019). The self-efficacy and modified sense of belonging items were designed by the external evaluator and reliability of the items were assessed using factor analyses in SPSS statistical analysis software. Exploratory factor analysis was performed on the data as part of another study that is pending publication. The population on which the first reliability analyses were performed were similar to the population of this study in

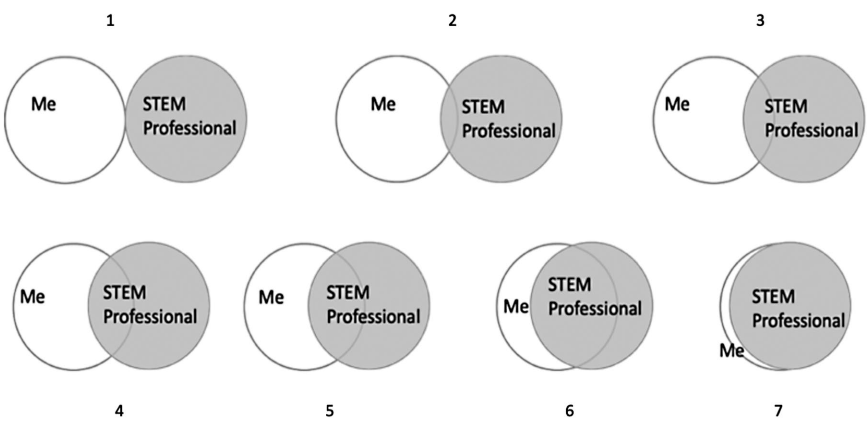

FIGURE 2. Science identity item used in the survey (McDonald, 2019). RISE in STEM program participants were instructed to select the picture that best describes the current overlap of the image you have of yourself and your image of what a STEM professional is. The responses were converted to numeric scores where 1 = the first image with no overlap, continuing counting upward as overlap increases so that 7 = the last image with almost full overlap.

that both were undergraduate, historically disadvantaged (first generation, low income, etc.) students in STEM. The items used for this study were found to factor into the constructs of self-efficacy in scientific problem solving and sense of belonging in the classroom with nine items factoring into the sense of belonging construct and 17 items into self-efficacy. Reliability for these factors was assessed during the original EFA process on a similar undergraduate STEM student population and the constructs exhibit high reliability where Cronbach's Alpha for self-efficacy in scientific problem solving was $\alpha = 0.92$ and sense of belonging in the classroom was $\alpha = 0.90$. Reliability tests were performed again on these items with the data from this study and revealed high Cronbach's Alpha for 17 self-efficacy items ($\alpha = 0.948$) and for 9 sense-of-belonging items ($\alpha = 0.805$). Because these items factor well together and exhibit high reliability, the items for each construct were computed into a mean score for the pre and post for each metric for analyses. The questionnaire was offered to students via the online survey platform Qualtrics. To match the answers over time, a unique, random, and anonymous code was generated for each student. The assessment of the impact included measuring changes from pre- (before intervention) to postsurvey (after intervention) and were analyzed using matched *t* test mean comparisons. Effect sizes were calculated using Cohen's d to determine whether small, medium, or large effect sizes were achieved in each quantitative outcome measure, per WWC standards ("What Works Clearinghouse standards handbook (Version 4.0)," 2017). Effect size reveals the extent to which the intervention is responsible for the measured change and is especially relevant when small sample sizes are used (Sullivan and Feinn, 2012). According to social science standards, effect is "strong" if the score is 0.8 or higher, moderate if the score is between 0.52 and 0.79 and small if it ranges between 0.21 and 0.5 (Fritz *et al*., 2012). For analysis, the data from each campus were combined to increase the sample size. The survey was administered only to the experimental group, using a one group pre/postdesign for this portion of the analysis because the intervention was expected to change student perceptions and the same changes were not expected in the control group (Mertens, 2019).

Student performance and retention

Student performance and retention data were gathered from the Institutional Research Office. It has been reported that students involved in CUREs feel lack of connection between the laboratory and the lecture topic. This may impact the student performance in the lecture portion of the course (Szteinberg and Weaver, 2013). Therefore, we evaluated the impact of the RISE in STEM program on student performance in the laboratory and lecture. Student grades in lectures were split by treatment lab and control lab (traditional lab) and were compared using statistical mean comparisons. Physics, biology, and chemistry instructors use a different grading scale so it was determined that reporting grades using quality (GPA) points would not show the most accurate results. Additionally, letter grades cover a span of 10 points so nuances would be lost by reporting only GPA. Therefore, the assessment used pass/fail and numeric course averages to assess performance between treatment and control groups. The students that withdrew were excluded from the pass/fail rates analysis for both treatment and control. Effect sizes were calculated using Cohen's d (via SPSS software) where d = 0.21 - 0.5 small effect, 0.51 - 0.79 moderate effect and 0.8 or higher indicates strong effect.

Pass rates for treatment courses were assessed and compared with control pass rates for the same course using institutional data and independent, summary *t* tests in SPSS. Letter grades were used to assess the rate at which students pass (D or higher) in each condition (treatment or control) for each course (physics, biology, and chemistry) and for both lecture and laboratory.

Retention data included students who withdrew from the treatment or control laboratory courses after the intervention during the Spring and Fall semesters of 2022. These comparisons were made using independent proportion tests in SPSS to compare the dichotomous variable of retention. To increase the sample size, results related to performance and retention from both campuses were combined and reported as treatment versus control for lecture and laboratory.

RESULTS

Student Perceptions

The science identity, sense of belonging, and self-efficacy in STEM of the participants increased after the implementation of the RISE in STEM program (Table 3).

The science identity posttest average (mean = 5.00, SD = 1.44) was higher and statistically significant ($p < 0.001$) when compared with the science identity pretest mean (mean = 2.58, SD = 1.60). The effect size calculated in SPSS using Cohen's d was large (ES = 1.41; 0.8 and above is considered a large effect), indicating that the intervention is associated with the increased mean scores in science identity.

The percentage of students that selected each science identity pictorial response before and after the intervention is shown in Figure 3. It is observed that 96.6% of the students showed higher perceptions of their own identity overlapping with what they see as a STEM professional after the intervention. The percentage of students that selected the pictorial responses numbered "1" and "2" decreased considerably after their participation in the program (1: from 30.5% to 3.4%; 2: from 32.2% to 1.7%). Conversely, the percentage of students that selected the responses numbered "5", "6", and "7" showed an increase (5: from 11.9% to 27.1%; 2: from 3.4% to 33.9%; 3: from 1.7% to 10.2%). These results suggest that the participation in the RISE in STEM program promoted the development of science identity in low-income Hispanic students.

The self-efficacy posttest average (mean = 9.24, SD = 1.49) was higher and statistically significant ($p < 0.001$) when com-

TABLE 3. Student perceptions on science identity, self-efficacy and sense of belonging using matched *t* test mean comparisons[a]

Psychosocial construct	Timing	Mean	*N*	SD	Sig	ES
Science identity	Pre	2.58	59	1.60	<0.001	1.41
	Post	5.00	59	1.44		
Self-efficacy	Pre	7.41	46	1.61	<0.001	1.09
	Post	9.24	46	1.49		
Sense of belonging	Pre	6.68	53	2.00	<0.001	1.14
	Post	9.03	53	1.21		

[a]The 17 self-efficacy items and 9 sense-of-belonging items were assessed as a whole construct with the computed mean for pre and post.

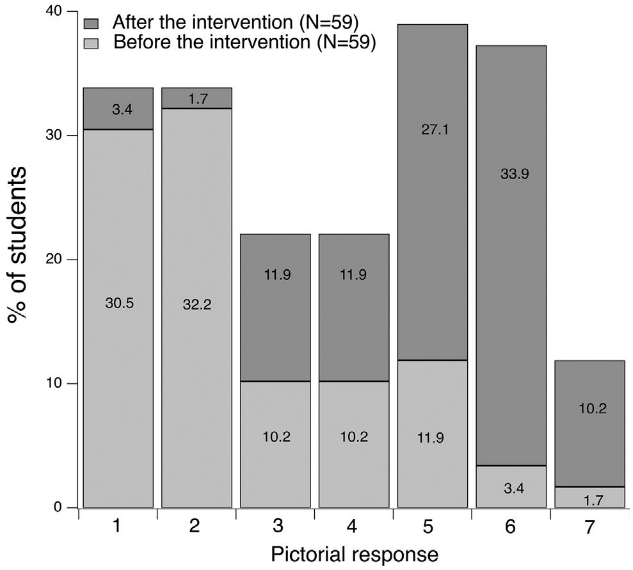

FIGURE 3. Percentage of students in each pictorial response before and after the implementation of the RISE in STEM program.

pared with the self-efficacy pretest mean (mean = 7.41, SD = 1.61). A large effect (Cohen's $d = 1.09$) was observed for this construct. The results also showed statistically significant improvement ($p < 0.001$) for sense of belonging (posttest: mean = 9.03, SD = 1.21; pretest: mean = 6.68, SD = 2.00) with large effect (Cohen's d = 1.14).

Student Academic Performance and Retention

Student success was measured by comparing both letter grades and numerical averages across treatment and control conditions for the three courses impacted by the program for both semesters combined. The findings showed that treatment students outperformed control students in pass rate and in numerical average (Tables 4 and 5). Independent summary *t* tests were used to compare the groups.

Chemistry, physics, and biology are considered rigorous courses where students commonly fail. Therefore, determination of the pass rates is of particular interest to evaluate the impact of the RISE in STEM program on student success. The results demonstrated that treatment students passed at a higher rate than control students in the lecture portion of the course (treatment = 97.3%; control group = 83.9%, p = 0.003). Similarly, the pass rate for students in the treated laboratory was higher than the pass rate of the control group (treatment laboratory = 100%, control group = 91.8%, p = 0.025; Table 4).

TABLE 4. Lecture and laboratory pass rates

	N	Percentage	Significance
Laboratory pass rate			
Control	90	91.8%	0.025
Treatment	60	100.0%	
Lecture pass rate			
Control	94	83.9%	0.003
Treatment	71	97.3%	

TABLE 5. Lecture and lab average grades

Numerical course scores					
	N	Mean (%)	SD	Sig	ES
Average lecture					
Control	112	73.11	19.26	<0.001	0.51
Treatment	73	81.56	10.61		
Average laboratory					
Control	97	80.39	17.72	<0.001	0.68
Treatment	60	91.17	11.96		

Additionally, numerical course averages were calculated for lecture and laboratory groups separately and compared across condition (treatment vs. control) as shown in Table 5. For the lecture, treatment scores were higher (mean = 81.56%, SD = 10.61) than those of the control group (mean = 73.11%, SD = 19.26). Student's grades for the treated laboratory course were also higher (mean = 91.17%, SD = 11.96) than grades for the control group (mean = 80.39%, SD = 17.72). The differences were found to be statistically significant ($p < 0.001$) and with moderate effect size where Cohen's d was > 0.5.

Chemistry, physics, and biology are gateway courses that are known to have low retention rates (Ferrare, 2019). Students usually withdraw from these courses at a high rate. Therefore, to evaluate the impact of the RISE in STEM program on treated laboratory courses, retention rates were examined. Independent proportion tests were used to measure significance of the differences in the means of both groups. The results demonstrated that the retention rates were higher for treatment students (99.9%) when compared with the control group (76.2%) and this difference was statistically significant ($p = 0.049$; Figure 4). These results, collectively, support the conclusion that the participation in the RISE in STEM program had a positive impact on student success across multiple measures (grades, pass rate, retention, science identity, self-efficacy, and sense of belonging).

DISCUSSION

In this study the impact of the RISE in STEM program (a multicampus collaborative CURE model combined with academic advising and peer mentoring) on Hispanic student perceptions

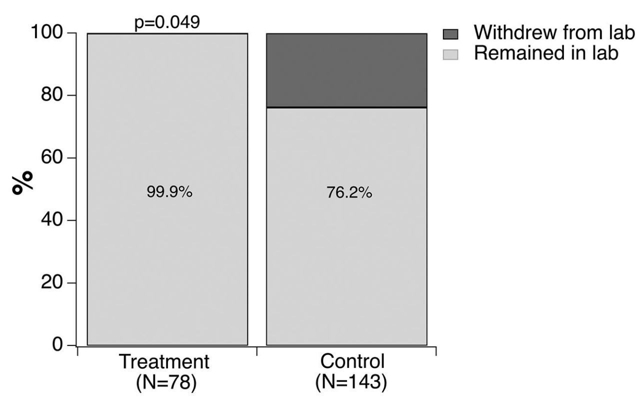

FIGURE 4. Retention rates for the lab sections. There was a significant difference in retention rate ($p = 0.049$) between the treatment and control groups.

and performance was evaluated. Student perceptions of science identity, self-efficacy, and sense of belonging are linked to improved persistence, performance, and retention in STEM (Ballen *et al*., 2017; Byars-Winston *et al.*, 2016; McDonald *et al*., 2019; Toven-Lindsey *et al*., 2015; Wilson *et al.*, 2015).

Science identity is broadly defined as recognition of oneself as a scientist (Carlone and Johnson, 2007; Hu *et al*., 2022; McCartney *et al.*, 2022). Research has found that this construct plays an important role on persistence and performance in STEM fields, particularly for underrepresented minority students (Carlone and Johnson, 2007; Merolla *et al*., 2012; Chen *et al.*, 2020). The RISE in STEM program provided an enriched environment that showed increased science identity in low-income, Hispanic students of whom 74.4% were women (Table 3). These results are relevant because it has been reported that Hispanic students have low science identity, with Hispanic females having the weakest science identity (Hazari *et al*., 2013). The percentage of students in the pictorial responses that indicated a high level of overlap (high science identity) increased after their participation in the RISE in STEM program (Figure 3). On the other hand, this percentage decreased considerably in those pictures where the overlap is minimal or null (low science identity) after the intervention.

Self-efficacy is the perception that an individual has about their own abilities to perform a particular task (Bandura, 1977). Many education researchers have defined science self-efficacy as the student's perceived confidence regarding their abilities in STEM (Williams and George-Jackson, 2014; Hu *et al.*, 2022; Sandrone, 2022). If a student is not confident in their STEM abilities, the level of self-efficacy is considered low. However, if a student is confident in their abilities in STEM, the level of self-efficacy is considered high. Improvements in this construct have been linked to improved outcomes of minority students and low-income students, including higher grades, and increased likelihood to persist in STEM (Rittmayer and Beier, 2009; Milner *et al.*, 2014; Carpi *et al.*, 2017; Kuchynka, Reifsteck, Gates, and Rivera, 2021). It has also been reported that students with low self-efficacy are more prone to leave STEM majors than students with high self-efficacy (Shaw and Barbuti, 2010; Kuchynka *et al.*, 2021). Our results demonstrated that students had a significant increase in self-efficacy after their participation in the RISE in STEM program (Table 3). The RISE in STEM program allowed target students (99% Hispanic and more than 80% low income) to conduct research in a collaborative setting where their STEM skills and their self-efficacy in STEM were improved. The findings demonstrated that students felt more confident in STEM after the intervention, indicating the development of a high level of self-efficacy in the low-income, Hispanic students at IAUPR-PC and IAUPR-BC.

Sense of belonging, the feeling of belonging or fitting into a group (Ruedas-Gracia *et al*., 2022), is connected to students' success, persistence, and retention, particularly for underrepresented minority students (Strayhorn, 2008; Walton and Cohen, 2011).

When it improves, students are more likely to stay and graduate with a STEM degree because they feel more comfortable as a scientist and supported in their field. Developing sense of belonging is considered a high priority due to the fact that its absence hinders the development of creativity, innovation, or desire for knowledge (Knekta, 2020). Our results showed that there was a significant improvement in sense of belonging of students who participated in the RISE in STEM program (Table 3). Research shows that engaging students in multiple activities increases their sense of belonging (Knekta *et al.*, 2020). As such, the RISE in STEM program provided a supportive environment with different activities, such as multicampus collaborative research, interaction with peer leaders and academic advisors, and a mini symposium that were proven to increase the students' sense of belonging.

In summary, the RISE in STEM program provided an optimal environment in three introductory gateway STEM laboratory courses (chemistry, biology, and physics) that improved three key constructs (science identity, self-efficacy in STEM, and sense of belonging) that are relevant for low-income minority students' academic performance and retention in STEM. Moreover, students that participated in the RISE in STEM program had higher pass rate and grades than students in the control group (Tables 4 and 5). Research has reported that students involved in CUREs feel lack of connection between the laboratory and the lecture topic which in turn may impact the student performance, especially in the lecture portion of the course (Toven-Lindsey *et al.*, 2015). Although the schedule used in the RISE in STEM model did not allow the topics of lecture and lab to be in sync with one another, this did not negatively affect students' grades; conversely, it positively impacted student performance. Additionally, the retention rate in the treated laboratory was higher than the retention rate in the untreated laboratory (Figure 4). These findings confirmed that the RISE in STEM program provided low-income, Hispanic students with remarkable tools for academic success.

LIMITATIONS AND FUTURE WORK

As a pilot study, the RISE in STEM program was able to gather data to measure impacts of the program on student retention, performance, and perceptions only. Although this study did not use prior academic achievement as a control variable in the analysis, the demographic characteristics of the control and experimental groups were very similar. Additionally, the control and experimental lab sections were scheduled at the same time for each course as established in the IRB protocol. This prevented the same CURE faculty from teaching both the control and experimental laboratory section. Therefore, the study is limited because the instructor of the control and experimental groups are not the same which makes the instructor a confounding factor that could not be controlled for in the study design or analysis. Another limitation is the use of a one group pre/postdesign for the student perceptions survey, where the control group was not administered the same survey. While literature supports the use of treatment-only pre/postdesign for certain situations, it can also be a limiting factor in the study's ability to generate strong evidence. Future iterations of this intervention would benefit from an attempt to survey the treatment and control groups and to attempt to control for the instructor so that the same person teaches both conditions. Finally, the RISE in STEM program plans to expand and explore more deeply which program components are associated with which impacts. To achieve this level of study, a larger sample is needed to support regression analysis.

CONCLUSION

Although the number of students entering science is generally increasing, disparities across demographic characteristics persist.

The present research suggests a link between student success and improvement of key constructs such as sense of belonging, science identity and self-efficacy. These constructs consistently had positive associations with performance and persistence in STEM, especially for underrepresented minority students. Therefore, pursuing programs and interventions to promote improvements on these constructs is an evidence-based way to address these disparities. Students that participated in the program showed an increase in the perceptions of their own science identity, their self-efficacy in STEM competencies, and sense of belonging in STEM. Additionally, improvements in pass rate and grades were observed for the treatment group. The components of the RISE in STEM program (multicampus collaborative research, peer mentoring, and academic advising) were responsible for this improvement. The RISE in STEM program provided real research experiences and opened a door for all students to engage in undergraduate research promoting educational equity. Incorporating collaborative CUREs combined with additional academic support into introductory courses will ensure every student has the same opportunity to engage with collaborative research and hone their skills of observing, questioning, making connections, and using evidence. These skills will enhance the students' learning experience throughout their university academic careers, as well as prepare them to address and solve problems or issues more effectively in their future careers.

Overall, this study found that combining multicampus collaborative CURE, peer mentoring, and academic advising led to improvements in performance, science identity, self-efficacy, and sense of belonging in STEM for low-income Hispanic students in STEM, furthering the evidence to support these activities and filling a gap in the literature concerning Hispanic students in Puerto Rico.

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