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Playing it SMART: increasing transfer student and URM undergraduate student success through undergraduate research combined with group support

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Increasing retention rates in STEM disciplines has been a primary goal among universities in recent years. Special attention has been given to increase STEM retention among underrepresented populations in those fields. However, one group of students that remains understudied but faces specific challenges is the transfer (TR) student population. TR students, and especially those who transfer from community colleges (CC-TR) in the US, often face academic and mental hurdles, loss of a sense of academic belonging, and adjustment challenges, sometime described as the "transfer shock." Undergraduate research, an experience that has been shown to promote student success, is often not pursued by STEM TR students due to a heavy load in their new 4-year university. We hypothesized that combining summer undergraduate research in STEM labs with intense group activities that focused on group support, development of research-related skills, and promotion of a sense of belonging, would increase rates of research participation after the summer among transfer students. Moreover, we hypothesized that such an intervention would promote student retention and academic success. Our research demonstrates that this intervention, through a summer program in an R1 university, served as a validating experience that increased participation in STEM research after the program, provided the students with academic skills, and improved graduation and STEM retention of TR and URM students. We believe that this intervention may serve as a model to promote student success among transfer and URM students.

KEYWORDS

transfer students, stem, undergraduate research, retention, academic belonging

Introduction

In recent decades, increased attention has been given to promoting participation and increasing retention of college students in STEM disciplines. The attention is reflected in the number of studies dedicated to this issue as well as to the variety of approaches and programs in the US at the college, state, and national levels to increase STEM accessibility and retention in higher education (National Science Board, 2022). A major focus has been given to under-represented minority (URM) and first-generation students (Clark, 2014; Ghazzawi et al., 2021). One of the promising approaches that was well studied and implemented in the last decade is the engagement of prospective and current URM students in STEM research (Hughes, 2018). In some studies participation in undergraduate research was the strongest predictor of likelihood of URM students to complete their STEM major(s) (reviewed in Chang et al., 2014). Highly popular are summer research programs for STEM majors and summer bridge programs for prospective STEM students (Barth et al., 2021).

One group of students that remains understudied but faces unique challenges in STEM retention is the transfer (TR) student population. TR students transfer from one college to another, often from a community college (CC-TR) to an R1-level 4-year university. TRs and CC-TRs are more likely to represent first generation, lower socioeconomic status, and racial or ethnic minorities (Dougherty and Kienzl, 2006; Sansing-Helton et al., 2021; Zukermann and Lo, 2021). More than 40% of undergraduate students in the US start their higher education in CCs (Sansing-Helton et al., 2021; Zukermann and Lo, 2021). Many aspiring high schoolers view the R1 4-year university [e.g., University of North Carolina at Chapel Hill (UNC-CH), which is the focus of this study] as their "dream school" but start their higher education journey in other in-state schools (typically CCs). This education pathway occurs for multiple reasons. Financial considerations weigh heavily for many. Other students were not accepted during their first application to the 4-year university, while some students prefer to first gain more confidence in their academic skills before moving to the big university. In a typical year at UNC-CH, a top research university we chose for our study, 16% of the incoming students are transfer students and about 44% of those students transferred from North Carolina community colleges.

Acceptance into a 4-university like UNC-CH is a celebrated moment in the lives of TR applicants, but for many of them the first semester at the new university presents multiple blocks and challenges. They need to adjust to a new university, to large classes, and sometimes even to new learning styles. Many CC-TR students take mostly general education classes at CCs and only a small set of STEM courses, which puts them at a disadvantage in the new university's STEM classroom as their peers already "learned how to learn" in STEM and understand the system better. The transfer experience often involves mental challenges, sometimes described as the "transfer shock" (Lakin and Elliott, 2016; Elliott and Lakin, 2021). Students who used to be in the top percentile of their class, find themselves struggling to pass a class, often accompanied by a sense of failure and an imposter syndrome response (see Theoretical Frameworks below).

Research Experiences for Undergraduate (REUs) are recommended by most higher education leaders, as a core element in STEM education (Kuh, 2008; Lopatto, 2010; Kuh et al., 2017). For example, the National Science Foundation (NSF) funds hundreds of REU initiatives every year (National Science Foundation, 2023). Mentored research project experiences have been utilized for many years and new ways to integrate research into the curriculum [e.g., course-based undergraduate research experience (CURE) classes] are being implemented across the nation (Bangera and Brownell, 2014; Buchanan and Fisher, 2022). Special focus has been given to use REUs as a way to improve success and retention of URM and first-generation students in STEM disciplines (Seymour et al., 2004; Ghee et al., 2016). With regards to undergraduate research, a major objective hurdle, which STEM TR students face (especially STEM TR students who follow a health profession track, e.g., pre-medical students) is the need to complete many STEM course requirements in a relatively short period of time. While their new R1 university offers excellent opportunities for students to engage in research, the TR students are much less likely to engage in research endeavors, because of so many classes they need to take in so little time.

A long-lasting NSF-funded program is The Louis Stokes Alliances for Minority Participation (LSAMP), with the mission "to assist universities and colleges in diversifying the nation's STEM workforce by increasing the number of STEM baccalaureate and graduate degrees awarded to populations historically underrepresented in those disciplines" (Louis Stokes Alliances for Minority Participation (LSAMP), 2023). NC-LSAMP is the North Carolina arm of LSAMP (North Carolina Louis Stokes Alliances for Minority Participation (NCLSAMP), 2023). It is an alliance of eight state universities, and while each university has its own program structure, the eight university members work tightly together as an alliance. Members meet, collaborate, share resources, offer conferences and awards to the students, carry assessments and research on their separate programs as well as for the alliance as a whole. UNC-CH is part of the NC-LSAMP alliance, implementing the Science and Math Achievement and Resourcefulness Track (SMART) program. SMART originated in 1996 and since 1998 has been focused on a summer REU for first year (rising sophomore) URMs.

While URM retention and success in STEM has been addressed by many REU initiatives, this research-based approach has rarely been used to address the population of transfer students. As mentioned above, the TR students, many of whom are part of populations underrepresented in STEM, have their own unique academic and mental struggles. In 2013, the late Dr. Pat Pukkila, who led the SMART program as well as the Office for Undergraduate Research at UNC-CH, decided to open a new arm of SMART, SMART-Transfer. She recruited a director (GS, author of this study) who developed the program. In the following summer the original SMART and the new SMART-Transfer programs merged, and the new SMART program has been active ever since.

The SMART program and the current study are based on the integration of two theoretical frameworks- the adjusted Tinto Model of retention and Rendón's validation framework. The original Tinto model suggested that social integration is as meaningful as academic performance, with regards to student retention (Tinto, 1975). The later work of Tinto and others noted that URM and Transfer students are two populations that specifically fit the model and would benefit from specific interventions from their academic institutions (French, 2017; Tinto, 1993). Rendón's validation framework addresses the doubts that underrepresented populations face upon entry into college, and how validating experiences can erase those doubts and promote student success (Holland Zahner and Harper, 2022; Rendón, 1994). Holland Zahner and Harper later showed how those validating experiences might differ between transfer and first year students, and how sense of belonging emerges as a significant factor that can be positively influenced by validating experiences (Holland Zahner and Harper, 2022). UNC-CH's SMART program is based on extensive research that showed how impactful undergraduate research is on student identity and success. The Tinto model of social support combined with Rendón's validation framework to positively impact students' sense of belonging, shaped the SMART program with the following goals: (1) to increase persistence in STEM research throughout their college career; (2) to provide the students with skills that would promote their sense of academic belonging; (3) to improve graduation and STEM retention of transfer and URM students.

The SMART program's approaches were the following:

1 To recruit a mix of first year STEM URMs with STEM junior transfer students (that already attended at least one semester at

UNC-CH). Each student received a stipend (funded in part by a grant from the NSF to NC-LSAMP).
2 Each student carried out a mentored research project for 9 weeks in a STEM discipline during the summer.
3 The SMART students met twice a week as a group with the SMART director, working on developing research-related skills: writing, reading, and communicating research. This gathering also served as a support group for the students.
4 Students were offered with additional social and academic activities such as workshops, panels, and lab tours.
5 All the students presented their summer research as part of a summer research poster symposium at the end of the summer.

In this paper, we tested our hypotheses that combining research intervention with group activities and support would increase rates of long-term participation in research, excellence in research (as demonstrated by completion of an honors thesis), rates of graduation and finally, rates of retention in STEM majors. The paper will discuss the outcomes of this study as well as provide in-depth description of the intervention program.

Methods

Study participants

All 163 SMART students were scored for demographics and field of study, including those that did not graduate or are still pursuing their studies (Tables 1, 2). Raw data of student demographics, study major and graduation status is found in Supplementary material 1. We did not record first generation status since the students were not required to report it. However, based on self-reporting as well as informal discussions, we estimate that about half of the SMART student body and a large majority of the non-URM SMART scholars were first generation students. Since 26 out of the 163 SMART students are still actively enrolled in the university, we tested the outcome numbers of the other 137 students.

TABLE 1 SMART demographics.

	FY	CC-TR	4-year TR	Total
Number of Participants	58	72	33	163
Gender				
Women	41	44	15	100
Men	17	28	18	63
Race and ethnicity				
Hispanic/Latino	13	27	2	42
Black/African American	24	8	3	35
Middle Eastern	1	8	2	11
Asian	13	3	8	24
American Indian	1	–	–	1
White	6	26	18	50

FY: students who started their 4 years at UNC-CH as first years; CC-TR: students who transferred to UNC-CH from community colleges. 4-Year TR: students who transferred to UNC-CH from 4-year universities. Data included all the 163 SMART students, including those who are still active student at the time of paper submission.

Data measures and analysis

Research rates

Rates of research for credit in biology were collected through the database of the Biology Department at UNC-CH. There are three reasons why biology data was used specifically instead of the entire UNC-CH STEM cohort. First, there is no available data for all the non-SMART STEM cohort in the university or in each and every STEM department. Second, in some majors (e.g., Computer Science) internship and volunteering are more common ways of engaging in research (compared with research for credit), and such activities are not always recorded. Third, biology is by far the largest major at UNC-CH and more than half of the SMART students over the years were biology majors. Moreover, the biology department keeps a consistent database of the biology students that have performed research through credit.

To assess research rates, we scored SMART and non-SMART students who pursued research for credit (BIOL 395) at least for one semester after the completion of the SMART summer program. For the non-SMART counterparts, we chose the 557 biology non-SMART students of the graduating class of the 2023 academic year (see Table 3). The reason we used that class and not the graduating class of 2021 (which was used as the control cohort in our graduation rates analysis, see below) is that the graduating 2021 class research rates were lower than usual due to the COVID 19 pandemic. We wanted to avoid a bias in favor of the SMART program when compared with the control cohort. Therefore, we assessed the non-SMART students of the graduating class of 2023 that were less impacted by the pandemic. To assess specific rates of TR students, we also scored the 113 non-SMART TR and 72 non-SMART CC-TR biology students from that same cohort of 2023 graduation class. A detailed statistical analysis, including p-values calculations, using a chi-square test can be found in Supplementary material 6.

Honors thesis completion rates

Honors thesis in biology is pursued by students who have completed at least one semester of BIOL 395, have sufficient data for

TABLE 2 Field of study.

Major	Number	Percent (%)
Total [a]	155	100
Biology	86	55.5
Chemistry	21	13.5
Neuroscience/Psychology	11	7.1
Math/Computer Science/ Statistics	18	11.6
Physics	5	3.2
Other STEM[b]	14	9

[a]Not including the participants who changed their major or withdrew from the university (see text for details). [b]Biomedical Engineering, Exercise & Sports Science, Radiological Sciences, etc.

a thesis, and maintain cumulative and biology GPAs of 3.3 or above. The Honors thesis class (BIOL 692H) can be taken by graduating seniors only. For the non-SMART cohort, we used the same 557 biology students from the graduating class of 2023 that served as control for assessing research rates (see above). We also scored the 113 non-SMART TR and 72 non-SMART CC-TR biology students from that same cohort to assess TR and CC-TR data. We measured rates of honors completion among biology students and not the entire UNC-CH cohort for the same reasons we described above for research rates assessment. A detailed statistical analysis, including *p*-values calculations, using a chi-square test can be found in Supplementary material 6.

Graduation rates

Graduation rates in 4 years of the full UNC-CH student body were collected from the UNC System interactive Data Dashboards-https://www.northcarolina.edu/impact/stats-data-reports/interactive-data-dashboards/. We used the data from the class that enrolled in 2017 and graduated in 2021, as this was the most updated data. We compared the UNC-CH data of that year to previous years and confirmed that this class represents typical rates. This cohort (see Table 4) consisted of 17,222 students, including 16,407 FY (2,593 of whom were URM students) and 815 TR students (370 of whom were CC-TR). We calculated the graduation rates of the SMART students by recording the students' graduation status through their individual UNC-CH records. Underrepresented minorities (URM) students were defined as those who are African American, Latino, Pacific Islander, and Native American. A detailed statistical analysis, including *p*-values calculations, using a chi-square test can be found in Supplementary material 6.

STEM retention rates

STEM retention analysis was based on comparison of a student's major(s) during their first term (intended or declared) and the major(s) on the completed degree. For non-SMART cohort controls, STEM retention rates were collected by the Office of Institutional Research and Assessment at UNC-CH. The graduating classes of 2021, 2022, and 2023 were available and showed very similar outcomes. We used the total numbers of these years to gain maximum statistical power. The STEM UNC control cohort consisted of 6,429 students, including 5,463 FY (951 of whom were URM students) and 966 TR students (485 of whom were CC-TR) see Table 4. SMART student rates were calculated based on their individual UNC-CH records. A detailed statistical analysis, including p values calculations, using a chi-square test can be found in Supplementary material 6.

Qualitative anonymous feedback

Anonymous student feedback was collected by the SMART program. During the first years of the SMART program, student feedback was submitted in print and later electronically through Qualtrics. A sample of the anonymous feedback form is found in Supplementary material 5.

Raw data, statistical analysis, an application form, a peer-feedback form, pre- and post-assessment student forms, and detailed student feedback can all be found in the Supplementary material.

This study received exempt approval from the University of North Carolina at UNC Institutional Review Board (IRB #24–0709).

Structure of the SMART program

Recruitment and selection of students and faculty

Recruiting students and encouraging them to apply to the SMART program was a multi-arm process. There was no single preferred system to successfully recruit competitive candidates. When recruiting URM students from UNC, emailing students through STEM departmental listservs and proactively contacting URM-based student organizations were effective. Sending emails to URM-based academic programs (e.g., Chancellor Science Scholars) and promoting the SMART program through classes also helped.

TR students were recruited through emails to STEM departments and to the C-STEP program (a successful admissions program that works with CC-TR students). Interesting to note that word-of-mouth proved to be a strong recruitment strategy. SMART alumni spread the word about the program to their CC-TR cohorts, and many of the latter applied.

The program application was based mainly on short paragraph responses to open ended questions, focused on the applicants' research interests, their long-term plans, how they could potentially contribute to the diversity of the program, and what they would want to gain from their summer experience (see Supplementary material 2). The applicants also added academic records related to their previous and current STEM course performance. Based on these applications, finalists were invited to an interview with the program director, followed by a final selection. In addition to the selected SMART students, several students were waitlisted, in case a selected applicant decided to decline.

The selection criteria were designed to ensure that grades in coursework were not the sole deciding factor. Instead, the roster was not restricted to students that excelled in all their academic endeavors. If there is one principle to highlight as a factor in choosing the most successful roster, it would be the word "mix." The program has always striven to create a mix of TR students with non-TR students, CC-TRs with non-CC TRs, students who got A grades in all STEM courses with students whose average was a C. Finally, some students already have had research experience while the majority did not. The goal was to create a diverse group that is composed of students who come with diverse skills and strengths and that can inspire and help their peers, especially during the group meetings throughout the summer.

The size of the roster varied from one year to the next, depending on funding. While the basic funding has always come from NSF (see NCLSAMP above), in some years the program was successful in obtaining additional short-term funding from university resources. The typical SMART roster in each summer consisted of 12 students, with eight being Junior TR students and four FYs. Eight to nine of those students were URM (typically Hispanic and Black) and the non-URM were mostly first generation, lower socio-economical background students who self-identified as Covenant Scholars (a need-based scholarship at UNC-CH). Before the program began, each student filled out a pre-program assessment form so we could learn more about their expectations and individual needs. A sample pre-program assessment form is found in Supplementary material 4.

With regards to identifying faculty mentors (PIs), students and faculty chose one another instead of being matched by the program. The SMART director guided students how to search for faculty mentors proactively and how to reach out in constructive ways. In parallel, the director contacted STEM faculty through departmental listservs and invited them to participate in the program. Faculty members who wanted to serve as mentors shared a short description of their research and potential projects, and then a list of all those labs was shared with the SMART students. In a typical summer, 40% of the students found faculty mentors through that list and 60% by actively searching for STEM faculty through University STEM databases.

After the roster of students and mentors was established, the director held a meeting with all the faculty mentors and co-mentors (e.g., graduate students) to explain the expectations, activities, and set the ground rules for interactions between mentors, mentees, and the program leadership in detail. Throughout the program, the director actively sought feedback about the students from the mentors and co-mentors.

Summer activities

Research project

This was the core arm of the summer SMART program. Each student performed a 9-week (30 h per week) hypothesis-driven research project in a STEM research group under the mentorship of a principal investigator (PI) and (typically) a co-mentor (e.g., graduate student, postdoctoral fellow). The PIs and co-mentors were coached in how to craft a project that was based on critical thinking instead of menial lab chores. The students then crafted their project objectives together with their mentors and gradually became independent. They designed the experiments, collected the data, analyzed the results, and reached conclusions. They also participated in regular lab group activities (e.g., lab meetings). In some cases, two SMART students worked in the same lab, but each had their own independent project. The summer research program ended with students presenting their achievements in the SMART group meetings and in the final poster research symposium (see below).

There was no concrete set of expectations for the level of results and data that the students should have achieved in those 9 weeks. The vast majority of the students stepped into a research lab for the first time in their life. The main goals were to gain scientific thinking and research skills, a sense of belonging, and to adopt self-identity as STEM scientists. Having said that, it is important to note that most of these students achieved impressive results in their projects in just 9 weeks of summer research, as evident from their posters, their mentors' feedback, and the fact that most of the mentors invited the students to continue with their projects in the following year/s.

SMART group meetings and activities

The students met twice a week for 90-min group meetings that were led by the program director. The groups consisted of up to 12 students.

The group meetings focused on the following elements:

a Group support. This element consisted of roundtable discussions where students shared their experiences in the laboratory including successes and failures and gave advice to each other.

b Development of scientific reading skills. During the first part of the program, the students learned how to read scientific papers and performed mock peer-reviews in small groups. With guidance from the director, each small group worked on a figure/table and presented it to the rest of the students, followed by group discussion.

c Development of writing skills. The students wrote an abstract on one of the papers that were discussed, and later wrote an abstract on their individual project. The abstracts were peer reviewed in small groups.

d Development of communication skills. During the second part of the program each student gave a 25-min chalk-talk style presentation on their research project.

The students also learned how to provide professional feedback on their peers' writing (abstract) and oral communication (chalk talk presentation). A sample peer-feedback form is found in Supplementary material 3.

Other activities

In collaboration with the UNC-CH Graduate School and School of Medicine, students were provided with additional professional development experiences including workshops (e.g., how to write a CV, how to write a personal statement), graduate student panel discussions, discussions about the URM experience in graduate school, visits to research facilities (e.g., National Institute of Environmental Health Sciences), and others. The students also met for social activities, both as a program and together with other summer programs (e.g., dining, sky-watching). All professional and social activities were focused on creating a sense of belonging and community.

Final poster symposium

At the end of the summer program, the SMART students joined other UNC-CH summer programs to celebrate their achievements in a poster symposium, which accommodated more than 100 students. The symposium was attended by students, faculty, and guests.

Post-summer

After the program was concluded, the students provided summaries, short PowerPoint presentations, and evaluations. Assessments were collected by the SMART director, by the UNC Office for Undergraduate Program, and by the NC-LSAMP evaluation team (see Supplementary material 5 for a sample form). The communication between the SMART students and the director continued during their college career and beyond through emails and a LinkedIn page with the goal of sharing career opportunities with the students. The students were also invited to NC-LSAMP and LSAMP conferences.

Results

In its current structure, the SMART program, which is geared towards transfer and non-transfer students, has been running for 11 years. During that period 163 students started the program. All 163 students successfully completed the program. Out of these students, 105 (64.4%) were transfer students and 72 transferred from community colleges (44.2%).

We tested student outcomes by examining participation in research for credit, completion of an honors thesis, rates of graduation and of rates of retention in STEM majors. We hypothesized that the summer intervention would lead to increased rates in some or all of these criteria, compared with controls (student counterparts at UNC-CH who did not participate in the program). Since 26 of the students who completed the summer intervention are still actively enrolled in the university, we tested the outcomes numbers of the other 137 students.

Completion of the summer research intervention predicts increased persistence in research and completion of an honors thesis

We hypothesized that that participation in the summer SMART program would ignite a flame of passion for research and that students would continue to pursue research during the following semesters after the program had completed.

Our follow-up revealed that many students continued and pursued research, some for credit, others through paid research or internship opportunities. Since paid research and internship data is lacking for the whole STEM student body, we focused our assessment on research for credit and specifically looked at Biology majors that pursued such research. First, credit is the major way for Biology majors at UNC-CH to pursue research (much more common than internships, compared with some of the other STEM majors). Second, Biology is the largest major at UNC-CH (with more than 500 majors graduating every year) and is the largest major represented in the SMART summer program (69 out of 137 assessed students). Thus, assessing the Biology majors allowed us to investigate robust data.

Of the Biology students who graduated in the 2022–23 academic year and were not part of the SMART program, 23% pursued at least one semester of research for credit (BIOL 395) at some point during their college career (Figure 1 and Table 3). This number represents a typical year in the Biology Department. In contrast, 73.9% of the biology SMART students completed at least one semester of BIOL 395 (3.2-fold higher rate than their counterparts). The numbers are even more striking when comparing SMART TR Biology students, of which 75% pursued research relative to 11.5% of their non-SMART TR peers, a 6.5-fold increase. Finally, there was a 10.7-fold increase in the percentage of students that pursued research for credit when we compared SMART CC-TR Biology students with their non-SMART CC-TR peers (73.7 and 6.9%, respectively).

TABLE 3 Rates of biology students who completed research for credit and of biology students that completed an honors thesis.

	Research for credit			Honors thesis		
	%	*n*	*p*-value	%	*n*	*p*-value
BIOL NON-SMART	23	557		7.9	557	
BIOL SMART	73.9	69	<0.0001	29	69	<0.0001
BIOL TR NON-SMART	11.5	113		0.8	113	
BIOL TR SMART	75	52	<0.0001	30.8	52	<0.0001
BIOL CC-TR NON-SMART	6.9	72		0	72	
BIOL CC-TR SMART	73.7	38	<0.0001	31.6	38	<0.0001

Research rates in percentages of students who completed at least one semester of research for credit in the Biology Department. The NON-SMART groups are the biology majors of the graduating class of 2023 who have not participated in the SMART program. BIOL NON-SMART and SMART: total numbers of biology majors. BIOL TR NON-SMART and TR SMART: biology transfer students. BIOL CC-TR NON-SMART and CC-TR SMART: biology transfer students who transferred to UNC-CH from community colleges. *p*-values calculations and statistical analysis are available in Supplementary material.

TABLE 4 Graduation and STEM retention rates.

	Graduation Rates			STEM Retention Rates		
	%	*n*	*p*-value	%	*n*	*p*-value
FY UNC	92.7	16,407		80.4	5,463	
FY SMART	100	45	0.61	93.3	45	0.33
UNC FY URM	90	2,593		75.2	951	
SMART FY URM	100	28	0.58	92.9	28	0.28
TR UNC	85.8	815		86.9	966	
TR SMART	95.7	92	0.31	98.9	88	0.23
CC-TR UNC	82.7	370		84.9	485	
CC-TR SMART	93.9	66	0.32	98.4	62	0.25

The Graduation rates of the NON-SMART groups are based on the students of the graduating class of 2021 of UNC-CH. STEM retention rates of the NON-SMART groups are based on the STEM UNC-CH students of the graduating classes of 2021–2023. FY and FY URM: Students who started their 4 years at UNC-CH as first years; TR: Transfer students; CC-TR: Students who transferred to UNC-CH from community colleges. All groups that include "SMART": students who participated in the SMART program. *P*-values calculations and statistical analysis are available in Supplementary material.

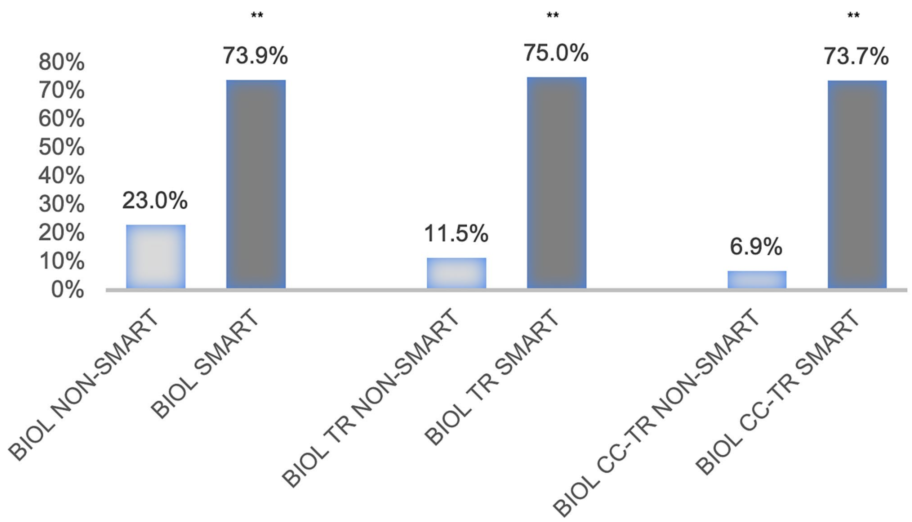

FIGURE 1
Biology SMART students completed research for credit at higher rates than their non-SMART cohort peers. Research rates in percentages of students who completed at least one semester of research for credit in the Biology Department. The NON-SMART groups are the biology majors of the graduating class of 2023 who have not participated in the SMART program. BIOL NON-SMART and SMART: biology majors ($n = 557$ and $n = 69$, respectively). BIOL TR NON-SMART and TR SMART: biology transfer students ($n = 113$ and $n = 52$, respectively). BIOL CC-TR NON-SMART and CC-TR SMART: biology transfer students who transferred to UNC-CH from community colleges ($n = 72$ and $n = 38$, respectively). ** $p < 0.0001$ (statistical analysis is available in Supplementary material).

As for URM students, research rates of biology non-SMART URM students is not available, so we could not compare research rates between SMART and non-SMART URM biology majors. However, it is worth noting the high research rates of the SMART URM biology students: 78.6% (22/28) of SMART URM biology majors and 82.4% (14/17) of CC-TR SMART URM biology majors completed their research for credit experience.

A senior honors thesis at UNC-CH is undertaken by seniors who have already completed at least one semester of research, obtained sufficient data, and maintained GPAs (cumulative and major-specific) of 3.3 or above. The students write a thesis, present their projects orally, and defend their thesis before Department faculty and their peers and families. Completion of an honors thesis is UNC's highest research achievement and only a small fraction of Biology seniors reach this bar. We hypothesized that the summer research intervention would lead to an increase in the rate of SMART students completing an honors thesis. 7.9% of the entire non-SMART Biology seniors pursued and completed an honors thesis, and only 0.8% of the Biology non-SMART TR accomplished that achievement. No non-SMART CC-TR students pursued an honors thesis in recent years. As shown in Figure 2 and Table 3, the Biology students who participated in the SMART program showed dramatically different numbers, with 29% of the Biology SMART students completing an honors thesis, 30.8% of the Biology SMART TRs, and 31.6% of the Biology SMART CC-TRs successfully defending their honors thesis.

As for URM students, honor thesis completion rates of biology non-SMART URM students is not available, so we could not compare research rates between SMART and non-SMART URM biology majors. However, the relatively high rates of the SMART URM biology students should be noted: 32.1% (9/28) of SMART URM and 41.2% (7/17) CC-TR SMART URM biology majors completed their research for credit experience.

Based on end-of-term anonymous student evaluations, the SMART students overwhelmingly found their summer research experience to be gratifying, and some mentioned it as an eye-opening experience. When students were asked to describe an area of development related to their summer research experience, critical thinking skills was the most common response. Highlighting the combination of failure and opportunity was also a recurring theme as students noted that they realized how many failures are involved in STEM research, but also how they developed to accept failures and to use them as opportunities for further success. The concept of being able to address failure came up also in the context of their self-identity as scientists. Below are a few sample quotes. Additional student responses can be found in Supplementary material 7.

Sample quotes:

1 *"Critical thinking, analysis, and independence. I tend to look for answers the easy way, such as ask someone directly without try looking for it myself. However, being in the research forced me to look for my own answers independently (with some help) and I am glad I gained that skill."*
2 *"I think the thing that I first learned was the amount of failure that can happen during research. As a result of the Summer program experience, I am able to handle failures better and engage in critical scientific thinking."*
3 *"I have learned that in research, challenges and errors are not obstacles, but rather opportunities for growth. Mistakes and unexpected results pave the way for new avenues of exploration leading to the continuous advancement of scientific knowledge."*
4 *"I now know that one research question does not always lead to the answer. It may lead to another question."*
5 *"My reasoning skills. I also developed my problem-solving skills and I am able to reflect on what can be wrong."*

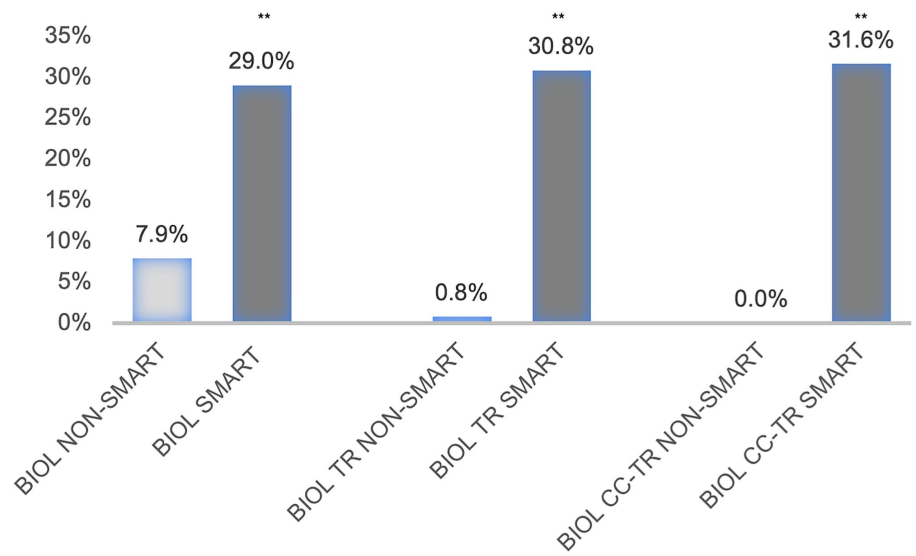

FIGURE 2
Biology SMART students completed an honors thesis at higher rates than their non-SMART cohort peers. Rates in percentages of students who completed an honors thesis in the Biology department. The NON-SMART groups are the biology majors of the graduating class of 2023 who have not participated in the SMART program. BIOL NON-SMART and SMART: biology majors ($n = 557$ and $n = 69$, respectively). BIOL TR NON-SMART and TR SMART: biology transfer students ($n = 113$ and $n = 52$, respectively). BIOL CC-TR NON-SMART and CC-TR SMART: biology transfer students who transferred to UNC-CH from community colleges ($n = 72$ and $n = 38$, respectively). **$p < 0.0001$ (statistical analysis is available in Supplementary material).

Completion of the summer research intervention predicts an increase in graduation and stem retention rates

The 4-year graduation rates of students entering UNC-CH either as first years (FY), transfer students (TR), and transfer students that started their journey at community colleges (CC-TR) were examined (Figure 3 and Table 4). Completion of the SMART program was correlated with a higher rate of graduation among all groups: 100% of FY SMART (including the FY SMART URM students) graduated in comparison with 92.7% of the non-SMART FY, and 90% of the non-SMART FY URM. As for TR students, 95.7% of the SMART TR students and 93.9% of the SMART CC-TR students graduated in comparison with 85.8 and 82.7% of their non-SMART cohort peers, respectively. It is important to note that among the four CC-TR SMART students who did not graduate from UNC, one student transferred to another UNC system university and later graduated from that institution. Thus, only 3 out of 137 SMART students did not graduate with a bachelor's degree.

We next compared the rates of retention in STEM majors among the SMART students who have already graduated relative to their non-SMART peers (Figure 4 and Table 4). STEM retention analysis was based on comparison of students' major(s) during their first term (intended or declared) and the major(s) on the completed degree. All the three groups of SMART students (FY, TR, CC-TR) showed higher levels of STEM retention compared with their non-cohort counterparts- FY: 93.3% vs. 80.4% for SMART vs. NON-SMART, respectively; TR: 98.9% vs. 86.9% for SMART vs. NON-SMART, respectively; CC-TR: 98.4% vs. 84.9% for SMART vs. NON-SMART, respectively.

Since URM FY students typically show lower STEM retention rates compared with non-URM students, we looked more closely at this population. We found that the increase in STEM retention rates was even greater when comparing FY SMART URM with FY UNC URM (92.31 and 75.2%, respectively).

Chancellor's Science Scholars (CSS) is a successful UNC-CH program, which is geared towards promoting STEM retention among URM students. When compared with their non-cohort control group (FY STEM with similar demographics), 83% of the CSS students retained STEM majors while only 58% of the control group retained their STEM majors (Sto Domingo et al., 2019). The URM demographics of the CSS FY students is very similar to the one of the SMART FY students, but unlike SMART, the CSS program is a 4-year program, which selects only outstanding students before they enter their first year at UNC. With that in mind, the SMART FY showed higher level of STEM retention (93.3% for FY SMART and 92.9% for FY SMART URM) compared with the CSS scholars (83%) and significantly ($p < 0.005$) higher retention rates when compared with the CSS non-cohort control students (58%).

Biweekly meetings as part of the summer intervention program promoted gain of student skills and sense of belonging

During each week of the SMART program, a major part of the bi-weekly group meetings was dedicated to developing research-related skills. We worked on scientific reading skills by analyzing three scientific papers, addressed scientific writing by learning how to write a paper abstract and then a project abstract. Finally, to develop their

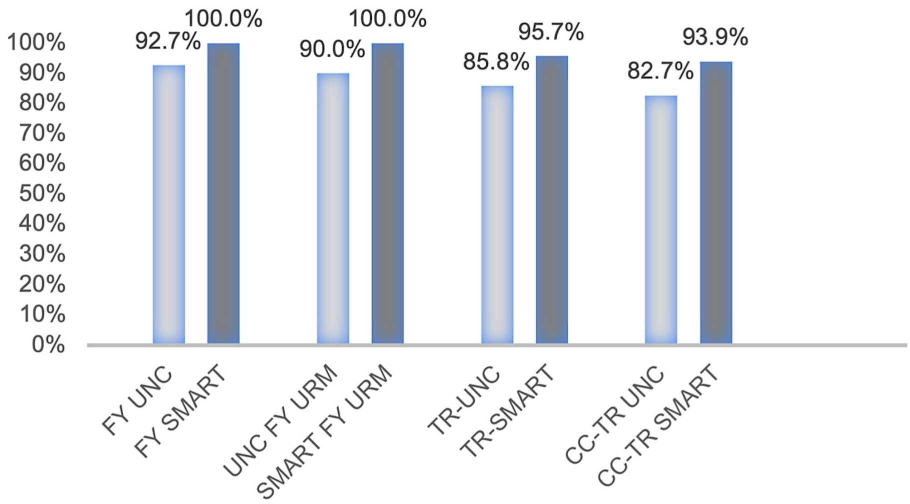

FIGURE 3
SMART students graduated at higher rates than their peers. Graduation rates in 4 years (in percentages) at UNC-Chapel Hill. FY and URM FY: Students who started their 4 years at UNC-CH as first years; TR: Transfer students; CC-TR: Students who transferred to UNC-CH from community colleges. The NON-SMART groups are the students of the graduating class of 2021 (the most updated available data from the UNC system, see Methods section above). FY UNC and FY SMART: $n = 16{,}407$ and $n = 45$, respectively. UNC FY URM and SMART FY URM: $n = 2{,}593$ and $n = 28$, respectively. TR UNC and TR SMART: $n = 815$ and $n = 92$, respectively. CC-TR UNC and CC-TR SMART: $n = 370$ and $n = 66$, respectively. p-values calculations and statistical analysis are available in Supplementary material.

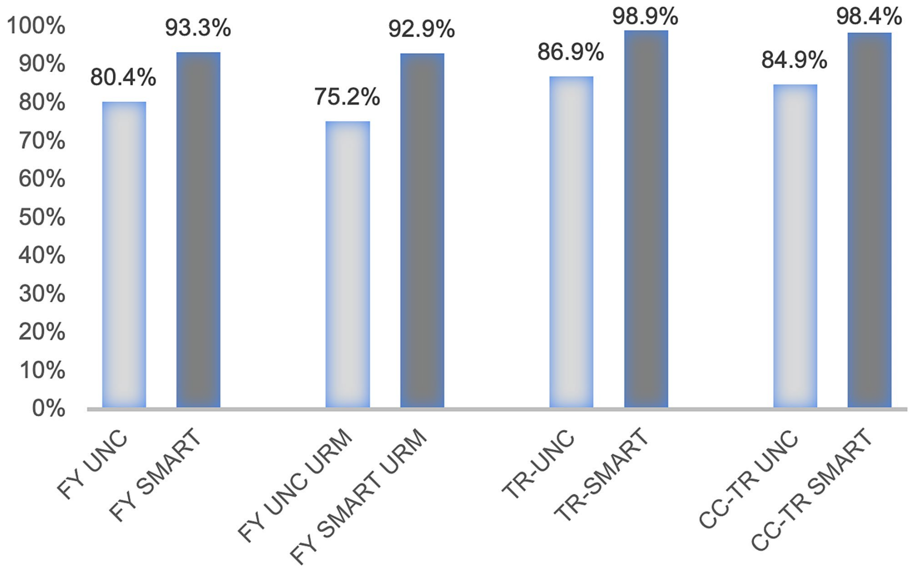

FIGURE 4
SMART students showed higher rates of retention in STEM majors than their non-SMART peers. STEM retention rates analysis was based on graduating student cohorts' majors at graduation compared to the major they declared during their first term. FY and URM FY: Students who started their 4 years at UNC-CH as first years; TR: Transfer students; CC-TR: Students who transferred to UNC-CH from community colleges. The NON-SMART groups are the UNC-CH STEM students of the graduating classes of 2021–2023 (see Methods section for more details). FY UNC and FY SMART: $n = 5{,}463$ and $n = 45$, respectively. FY UNC URM and FY SMART URM: $n = 951$ and $n = 28$, respectively. TR UNC and TR SMART: $n = 966$ and $n = 88$, respectively. CC-TR UNC and CC-TR SMART: $n = 485$ and $n = 62$, respectively. p-values calculations and statistical analysis are available in Supplementary material.

science-communication skills, each student gave a 25-min chalk talk on their research project as well as presented a poster at the Undergraduate Summer Research Symposium. The students also learned how to provide professional feedback on their student writing (abstract) and oral communication (chalk talk presentation).

Each student rated each research-related activity on a 1–10 scale (10 being the highest). All activities received high scores from the students, with medians of 8 or above (Table 5). The average score of all the activities (summed together) was 8.61 with a median of 9. Thus, the students found all research-related

TABLE 5 Scores in a 1–10 scale given by the SMART participant to different group activities.

	Paper analysis	Scientific writing	Chalk talks	All activities
Average	7.79	8.66	9.34	8.61
Median	8.0	9.0	10.0	9.0
SD	1.74	1.65	1.3	1.68

Scores of each of the research-related activity (10 being the highest), as rated by the SMART students on their anonymous end-of program feedback ($n = 163$).

activities to be a strong positive factor that contributed to their development.

Recurring themes in the anonymous student feedback were the power of critical reading and importance of the chalk talk to development of communication skills and a better understanding of their research projects. Frequently, students entered the program with a "textbook science" mentality, believing that all published research must be true. Learning how to scrutinize a published manuscript developed critical thinking skills by empowering students to differentiate between well-supported and ill-supported claims in the literature. Many students were stressed and nervous before giving their chalk talk, but they ultimately found that organizing the talk and presenting it were some of the highlights of their summer experience.

Sample quotes (additional student responses can be found in Supplementary material 7):

1 *"I always thought that whatever info that came from a scientific journal must be true, but now I will be more careful reading paper."*
2 *"Peer review- so important! Has helped me to develop a skeptical eye and be on the lookout for bad science."*
3 *"I really enjoyed and benefited from discussing and critiquing research papers. I have always thought that a paper being published means that everything in it is valid, and it is extremely valuable to learn how to interpret the quality of a paper."*
4 *"The most challenging part was the chalk talk, but it was highly rewarding. Only after it, did I actually know what was happening in my lab and where do I stand. I also realized the importance of my research and the effect it has on the community."*
5 *"I am very shy when it comes to speaking up in front of any group of people, when I do not know them, so these meetings helped me expand my horizons and get out of my comfort zone."*

One of the main goals of the program in general and the group meetings in particular was to promote a sense of belonging among the students and to develop their self-identity as scientific scholars. Therefore, beyond working on research-related skills, time and effort were also dedicated to peer support. For example, we had weekly roundtable discussions where each student shared updates on their project as well as highlighting failures and achievements. Students were also encouraged to share challenges they experienced in the lab including issues with benchwork and relationships with their mentors. In their feedback the students emphasized the importance of the group support to their success, how this program made them feel as real scientists, and how they now feel as they are an integral part of the scientific community.

Sample quotes (additional student responses can be found in Supplemental material 7):

1 *"If I would describe this summer's research experience as one, that will be challenging. I was challenged to learn scientific terminology as well as protocols that at the beginning I had no idea existed. However, this dynamic motivated me to keep improving my skills and knowledge. I failed so many times, and deep inside I knew that will happen, but what I wasn't prepared for was the excitement of doing things again with such stamina because this time I knew what when wrong and where I could improve. I gained a lot of confidence, and I would not change the hardest weeks for nothing because from them I learned how to be a stronger scientist."*
2 *"My overall experience was amazing. There wasn't much time to really absorb how much I learned/developed but right now thinking about it, I feel extremely accomplished and know that without this program, I would not be where I am today, not even close."*
3 *"It allowed me to feel more included in the community."*
4 *"Group meetings- this was very important. We were all going through the same experiences, and being able to see that, encouraged me to continue with my project."*
5 *"Group meeting: Very important, hearing their struggles and successes made me feel at home and eased the pressure of my first research experience."*
6 *"The meetings were a critical part of the experience. I knew I had a safe space to communicate my thoughts. It felt so comforting to have a group of friends you were going the same experiences as me."*
7 *"I found this environment crucial to my sustainability. There were many times that I felt overwhelmed or stressed, but my group members found a way to relate with me and to help me feel more at ease."*

Discussion

The transfer path from a community college to a 4-year university has the potential to serve as an important way to diversify the STEM disciplines, since a high percentage of the transfer student body overlaps with populations under-represented in STEM (Holland Zahner and Harper, 2022; Dougherty and Kienzl, 2006; Sansing-Helton et al., 2021; Zukermann and Lo, 2021). However, TR students often experience challenges in adjusting to a 4-year university. They need to "catch up" with their peers and to complete a heavy load of STEM classes in a relatively short period of time. This and other challenges often hurt their sense of academic belonging. Unlike at their previous institution, TR students are often no longer at the top of their class – they may be the ones who struggle to get a C grade in their new university. Academic belonging is a significant factor in students' intentions to persist and complete their STEM degrees. Therefore, it is not surprising that many TR STEM students drop their major, and sometimes even withdraw from the university (Elliott and Lakin, 2021; Holland Zahner and Harper, 2022; Lakin and Elliott, 2016).

These challenges combined with the documented success of REU programs in improving a sense of belonging and improving STEM retention among URMs inspired us to design the SMART program to include transfer students. The goal of the SMART program was not simply to select for "the best," but instead to create a diverse environment where peers influenced and supported one another to allow the whole group to reach their full potential. To achieve these goals, we combined the traditional research experience with two additional features that we hypothesized would be critical. First, we made sure to have a mix of transfer students and non-transfer URM students, and we made sure that there would always be a mix between students with a stronger background and students who struggled in their STEM classes. Second, we made sure our group meetings had an emphasis on group support. We hoped that the group activities would synergize together with the research environment to help students feel as though they were an integral part of the scientific community.

Eleven years after the SMART program adopted its current format, we believe that the student outcomes demonstrate how the SMART experience achieved the three main goals of the program- to increase persistence in research, to increase rates of graduation and retention in STEM majors, and to develop a sense of academic belonging.

Persistence in research

The passion for research helps drive success in STEM. Undergraduate research has been highlighted as one of the core High Impact Practices (HIPs) and has shown to increase the motivation of STEM students, their academic performance, their retention in STEM, and their ability to gain skills that will help them prepare for future careers (Kinkel and Henke, 2006; Kuh, 2008; Lopatto, 2010; President's Council of Advisors on Science and Technology, 2012; Chang et al., 2014; Kuh et al., 2017). Transfer students, on the other hand, participate in research in much lower numbers (Figures 1, 2 and Table 3). They find it remarkably hard to get engaged in research with so many STEM classes to take in only a few semesters. Research for credit in most STEM disciplines requires at least 10 h of lab work each week and is not necessarily viewed as an essential, or even advantageous endeavor for transfer students who need to dedicate most of their free time to the rigor of STEM classes. We hypothesized that participation in SMART would motivate TR students to continue with research after completing the program. Our results show that the rates of TR students who participated in research and of those who pursued an honors thesis were strikingly higher than their non-cohort counterparts. Moreover, these SMART TR research and honors completion rates were significantly higher even than those of the non-TR population of students (Figures 1, 2 and Table 3).

One limitation to this part of the study is that research and honors completion rates were assessed only among the biology SMART and non-SMART cohorts for reasons described above in the Methods and Results sections. We cannot rule out the possibility that these results do not necessarily apply to other STEM disciplines. However, it's worth noted that the biology cohorts, both in the SMART and the UNC-CH student bodies are disproportionally the largest group of cohorts. In addition, the qualitative anonymous students feedback (which was not limited to biology students) suggests that the summer research experience was similarly beneficial to students from all STEM disciplines.

Accordingly, SMART students stated that without the SMART experience they would have not pursued research later (e.g., "*I feel extremely accomplished and know that without this program, I would not be where I am today, not even close.*"; "*Transferring credits from a community college makes fitting in a research project difficult. I honestly do not think I could have done research without this program*").

Graduation and STEM retention rates

The rates of graduation and of retention in STEM majors of the SMART students (including the SMART TR students) exceeded those of their non-cohort peers from the same institution (Figures 3, 4 and Table 4). These rates are even more impressive when compared to data from the state and the country. A limitation of this part of the study is that the increase in graduation and STEM retention rates were not statistically significant. This is expected, given the low statistical power of this specific set of data to begin with (relatively high rates in the non-SMART control cohort as well relatively low sample of SMART students). However, it is important to note that (1) all groups and subgroups of the SMART program showed a trend of higher rates compared with their non-SMART control cohort, and (2) in the CSS study mentioned above in the results section (Sto Domingo et al., 2019), the control group (which has a higher match with the SMART students study disciplines and demographics) showed statistically significantly lower STEM retention rates than the SMART students of this current study.

The numbers above should be taken with caution. Like any other application- and selection-based program, a selection bias should always be considered when analyzing outcomes. However, several points suggest that these impressive numbers provide a realistic picture. First, the SMART TRs faced the same time and rigor constraint as their non-cohort peers, and yet they participated in research six times more than the non-SMART students and three times more than the entire student body. Second, SMART students themselves stated that without the SMART experience they would have not pursued research later. Third- CSS scholars, a highly selective group at UNC-CH with similar demographics to SMART FY students, showed lower retention rates when compared with SMART FY (see result above). Finally, the SMART selection process did not focus on only the best academic performers. In fact, we intentionally chose a mix of students who did well with those who did less well. There are many SMART students who graduated with a GPA lower than 3.0, including some at the level of a C(−) average GPA. These students continued to do research and some of them continued to graduate schools, clinical research in pharmaceutical companies, and research careers in the industry. In summary, while the impressive numbers should be taken with caution, multiple data points suggest that pursuing the SMART program increases one's likelihood to continue with research, to stay in a STEM major, and to graduate.

Sense of academic belonging

Undergraduate research programs come in different shapes and sizes. Regardless of the program structure, the actual research component is generally considered to be the most significant experience for students. We believe that the addition of group activities, such as those included in the SMART program, played a significant role in student success. Using meetings to develop research-related critical thinking skills (including reading, writing, and communicating science) was helpful by itself, but peer support and cohort building was an added benefit of group activities. The students felt validated and were proud to be part of a strong scientific community. This idea is strengthened by previous research showing that peer support is one of the strongest positive predictors of sense of belonging (Blaney et al., 2022).

In times of limited human and financial resources, university administrators need to prioritize their efforts and to find the most effective ways to promote inclusion of specific populations of students in research as well as to increase retention in STEM. Based on our data, we suggest that the SMART program can serve as a positive model for undergraduate student research programs. By combining mentored research with additional group activities, we produced a cost-effective summer program that benefits a wide range of student populations. It is noteworthy that many of our SMART alumni continued to graduate school, STEM-related industry, or followed health-provider careers.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

GS: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

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In memoriam

This paper is dedicated to the late Pat Pukkila, who pioneered undergraduate research at UNC-Chapel Hill in general, and transfer student research in particular, and who gave me the opportunity to craft and lead the SMART program in 2013.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1465803/full#supplementary-material

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