Implementation of a Holistic Graduate Student Development Model Through the Bridge to the Doctorate Program (Research)

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Introduction:

The United States' scientific and economic competitiveness depends on a robust, diverse STEM talent pipeline, yet longstanding inequities continue to depress doctoral attainment among populations historically underrepresented in Science, Technology, Engineering, and Mathematics (STEM) fields. National indicators show persistent underrepresentation of Black, Hispanic/Latino, American Indian/Alaska Native, and Native Hawaiian/Pacific Islander scholars among STEM degree recipients and workers relative to their representation in the U.S. population, underscoring a national priority to expand participation across graduate education and the research workforce [1, Vol. 46]. Historically Black Colleges and Universities (HBCUs) have been central to meeting this priority: although they enroll a minority of Black undergraduates, HBCUs are consistently among the top baccalaureate origins of Black STEM Ph.D. earners, demonstrating a distinctive institutional capacity to cultivate doctoral aspirations and success [1, Vol. 46], [2].

Within this landscape, the NSF Louis Stokes Alliances for Minority Participation (LSAMP) and its Bridge to the Doctorate (BD) component address critical transition points in the pathway from baccalaureate to doctorate. LSAMP-BD provides two years of graduate funding and structured support to former LSAMP scholars with the explicit goal of Ph.D. matriculation and completion, an approach that evaluation evidence links to increased master's degree attainment and higher doctoral completion among students who begin in master's programs [3]. The BD implementation described in this paper—at an HBCU, North Carolina A&T State University (N.C. A&T), for a cohort of 12 fellows entering STEM graduate programs—builds on this evidence and on N.C. A&T's demonstrated strengths by combining financial stability, multi-layered mentoring, cohort-based belonging, professional development, including Accelerate to Industry (A2i), and proactive fellowship preparation to reduce well-documented barriers to Ph.D. completion. (Program details summarized here were collected through institutional surveys, focus groups, and exit interviews conducted from Fall 2024 to Spring 2025.)

National reviews have repeatedly linked diversity in STEM to enhanced innovation capacity and economic competitiveness, and have called for targeted interventions that couple academic support with social integration and mentoring [4]. HBCUs, in turn, provide affirming, mission-driven learning environments that foster belonging and persistence in STEM, helping explain why so many Black STEM doctorates trace their baccalaureate origins to these institutions [5]. Yet even strong undergraduate preparation must be matched by graduate-level structures that mitigate known risk points for attrition, such as financial precarity, variable advising quality, limited professional networks, and diffuse guidance on funding and career trajectories. Evidence from the Council of Graduate Schools' Ph.D. Completion Project identifies mentoring/advising, financial support, and program environment as among the most influential determinants of doctoral completion across fields and student subgroups [4], [6].

The BD model directly targets these key determinants. Prior national evaluation shows that LSAMP-BD's combination of early graduate funding and purposeful mentoring increases progression, especially for students who initially enroll via a master's route, thereby addressing a common entry pathway for underrepresented scholars [3]. By situating BD at an HBCU with a cohort design, this implementation further leverages HBCUs' strengths in community-building and culturally responsive support to promote STEM identity, belonging, and persistence [2].

Undergraduate research and entry-to-graduate programs such as the Ronald E. McNair Postbaccalaureate Achievement Program (a federal TRIO program) prepare disadvantaged and underrepresented undergraduates for doctoral study through research experiences, mentoring, and graduate admissions support, with national reporting documenting graduate enrollment and doctoral attainment among McNair alumni [7], [8]. In the biomedical sciences, NIH's BUILD and MARC initiatives similarly develop research skills, mentoring networks, and graduate-school readiness for participants from underrepresented backgrounds [9]. These programs are crucial on-ramps, but they typically conclude at baccalaureate completion or graduate matriculation; BD is designed to pick up at the next, often precarious, stage by stabilizing the first two graduate years and providing intensive mentoring and community during the transition to doctoral research.

Masters-to-Ph.D. bridge models further illustrate the power of cohort-based, mentored transitions; for example, the Fisk–Vanderbilt Master's-to-Ph.D. Bridge Program reports high rates of bridging to Ph.D. programs and strong retention and completion among underrepresented students in the physical sciences [9], [10]. BD complements such models by offering a broad, cross-discipline HBCU-based bridge that embeds similar design principles (multi-tiered mentoring, skills-building, and community) for a multi-program cohort, while also aligning with LSAMP's national network and resources.

Graduate-stage ecosystems such as the NSF Alliances for Graduate Education and the Professoriate (AGEP) and the Alfred P. Sloan Foundation's University Centers of Exemplary Mentoring (UCEM) work with graduate schools to improve recruitment, mentoring climates, and retention for underrepresented doctoral students. Evaluations and syntheses from these efforts emphasize comprehensive mentoring, professional development, well-being, and financial support as pillars of doctoral success and pathways to academic careers [11]. BD fellowships are synergistic with these ecosystems: by providing early graduate funding, networked mentoring, and professional development in the first two years, BD cohorts are well-positioned to thrive within AGEP- or UCEM-enhanced programs and to take advantage of those institutions' broader mentoring infrastructures as they advance to candidacy [3], [11].

External fellowships (e.g., GEM in engineering and computing) expand access to funding, research experiences, and industry networks for underrepresented graduate students, improving persistence and career placement [12]. The BD site described here integrates a Summer Fellowship Application Preparation Program (SFAPP) and A2i modules to strengthen applications and career readiness, approaches consistent with evidence that financial security and structured professional development reduce time-to-degree and attrition [4]. A2i, developed at NC State and disseminated nationally, provides job-search strategies, company site visits, internships, team practicums, and immersion experiences that build business, leadership, and communication skills valued by employers, resources particularly relevant for doctoral students exploring diverse career pathways [13].

Research on mentorship and socialization in STEM underscores that effective, multi-mentor networks, paired with explicit mentor training and clear expectations, benefit all doctoral students and may be especially consequential for those from historically marginalized groups. The National Academies' *Science of Effective Mentorship in STEMM* synthesizes this evidence, calling for structured, culturally responsive mentoring that goes beyond dyadic advising to include mentor networks, peer communities, and program-level supports [14]. The BD implementation aligns with these principles through monthly cohort meetings, one-on-one and small-group mentoring with the leadership team, alumni mentoring, and programmatic attention to building a sense of belonging—features that fellows identified as among the most valuable components of the experience.

Moreover, comprehensive undergraduate-to-doctorate models such as UMBC's Meyerhoff Scholars Program have shown that cohorts, intentional mentoring, early research experiences, and robust financial support substantially increase STEM Ph.D. entry and completion among underrepresented students, a pattern consistent with the mechanisms BD seeks to activate at the graduate stage [15, p. ar48]. Together with CGS findings on the centrality of mentoring/advising, financial support, and supportive program climate, this literature suggests that the BD program's layered financial, mentoring, and community structures directly target determinants of doctoral success [4].

Anticipated contributions and significance. By integrating evidence-based practices within an HBCU context—streamlined cohort enrollment, paid fellowships in the first two years, multi-tiered mentoring networks, professional development workshops, A2i industry-facing experiences, and proactive fellowship/grant preparation—this BD program addresses structural barriers that frequently impede doctoral progression for underrepresented students. It complements upstream programs (McNair, BUILD/MARC, LSAMP undergraduate), aligns with bridge models (e.g., Fisk–Vanderbilt), and dovetails with institutional capacity-building efforts at the Ph.D. stage (AGEP, Sloan UCEM), thereby strengthening a continuum of support from baccalaureate through doctorate and into the workforce [7], [9], [10], [11]. In doing so, it advances national goals to broaden participation and sustain U.S. leadership in STEM by increasing the number of well-prepared Ph.D. graduates from historically underrepresented groups. The purpose of this program is to prepare a cohort of 12 LSAMP Bridge to the Doctorate Fellows to persist in STEM Ph.D. programs at North Carolina A&T State University. More specifically, (1) Enroll a cohort of 12 verified LSAMP scholars into STEM graduate degree programs at N.C. A&T; (2) Implement a comprehensive program that prepares, retains, and enables BD Fellows to successfully undertake STEM doctoral programs; and (3) Provide support to BD Fellows beyond BD funding in preparation for graduation and career.

Description of the Intervention:

The **BD Program** utilized a systematic approach to effectively support students in degree completion and career success. A multi-pronged collaborative model that integrated the evidence-based domains of: (1) self-efficacy, (2) science/research identity, and (3) social cognitive career theory is visualized in **Figure 1.**

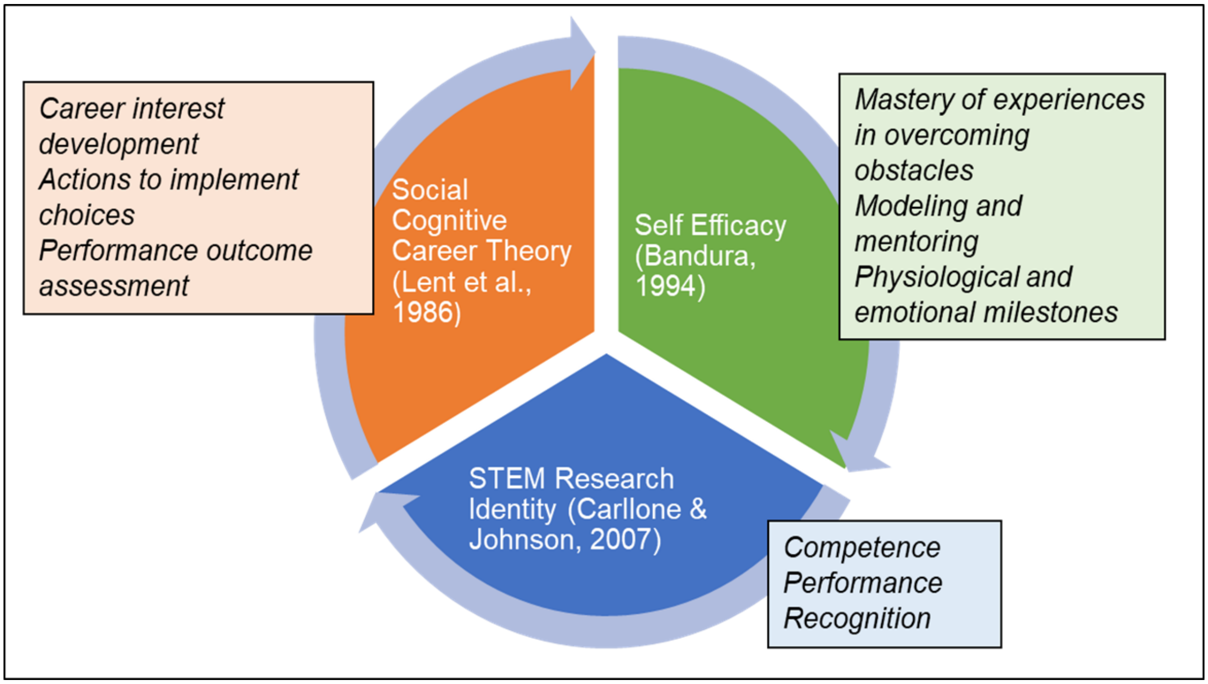

Figure 1: Theoretical framework and model for the BD program. All three aspects were considered when supporting BD fellows[16, pp. 1187–1218], [17, pp. 261–271], [18, p. 265].

North Carolina Agricultural and Technical State University (N.C. A&T) is an 1890 land-grant doctoral research institution with a distinction in STEM and commitment to excellence in all disciplines, N.C. A&T faculty, staff, students, and alumni create innovative solutions that address the challenges and economic needs of North Carolina, the nation, and the world. With an enrollment of more than 15,000 students, it is the largest HBCU in the country, the number one producer of degrees awarded to African Americans in North Carolina, and is nationally recognized for excellence in STEM education. We believed students recruited into and supported through this culture would benefit from the overall experience. Therefore N.C. A&T was an excellent testbed for the rollout of this mentoring model.

The initial cohort of BD Fellows was established, from a variety of programs. Three key recruitment strategies that have proven to be useful are described below:

Strategy 1: Engage targeted doctoral programs. BD Fellows were recruited to matriculate in Ph.D. programs in four N.C. A&T colleges: The College of Engineering, College of Science and Technology, Joint School of Nanoscience and Engineering, and College of Agriculture and Environmental Sciences.

Strategy 2: Execute targeted recruitment activities. Special recruiting efforts were offered to students interested in entering a doctoral program directly from their baccalaureate degrees. This included leveraging the national network of LSAMP programs to ensure that our BD cohort reflects both disciplinary and demographic diversity.

Strategy 3: Widened spectrum of recruitment activities. Lastly, we infused LSAMP recruiting across N.C. A&T's many existing recruiting activities. These activities include attendance at more than 50 Graduate Career Fairs, across 17 states and include HBCUs, R1, and R2 institutions. We also recruited at discipline-specific events, *i.e.*, the ACM Richard Tapia Celebration of Diversity in Computing, the National Society of Black Engineers Conference, and the Society of Women Engineers Conference.

In addition to direct, in-person recruitment activities, promoted and recruited through our websites and social media. A dedicated website for the BD program provided details about eligibility requirements, the application process, and the benefits of the program. Best practices included an interest form so prospective applicants left their contact information for personalized follow-up. Rapid follow up included a QR code or web address to our application portal and a website with more information about the program. As well as a website that has more information about the program. Once the student has found the portal, demographic and contact information was collected. Students were asked to answer questions regarding their participation in the LSAMP program during their undergraduate studies, upload a copy of a resume or CV, an unofficial transcript, a letter of recommendation and a three-page maximum personal statement.

Application assessment procedures included the review of the materials to ensure that the student is a US citizen, participation in LSAMP as an undergraduate student, eligibility for direct entry into one of the STEM PhD programs outlined above, and a review of their personal statement to gauge interest in graduate studies. If all the criteria were met the prospective fellow was sent an offer letter detailing the award, noting the funding is contingent upon them being accepted to one of the eligible STEM Ph.D. programs.

An important aspect of this program was the financial support. To address this problem, the program offered each fellow a stipend and funds applied towards educational costs for the first two years the student was in the program. It was expected that after those first two years, the student would be supported by funds from their adviser or by securing additional fellowships.

After the offer of support was accepted, each fellow was successfully registered and completed one academic year in their graduate programs. This included ensuring that all fellows received the proper academic advising. Major activities for the LSAMP Bridge to the Doctorate program included the following:

- Academic Advising – to ensure timely matriculation of the twelve BD Fellows, it became of critical importance to make sure BD Fellows registered for the proper classes. To accomplish this goal the program team worked diligently to provide accurate advising regarding planning for classes. The entire cohort did register for classes and completed their first year of graduate studies.
- Professional development sessions
- Mentoring in 1-on-1 and small group sessions with members of the program's leadership team, and mentoring through Mentor Collective, an external vendor.

As a cohort the scholars participated in a matched mentoring experience through an external vendor, Mentor Collective. As an external vendor, Mentor Collective serves as a conduit to establish and maintain mentoring relationships between students and mentors. In the fall, we sent information to the BD Fellows, asking them to complete a questionnaire about their career path, education, and mentoring needs. We compiled a list of mentors consisting of alums who received a graduate degree from our and other institutions, including those who worked in industry. All mentors receive training on good mentoring practices and provided information on meeting availability. Each mentoring pair is responsible for establishing a meeting schedule and used the internet-based interface to log interactions. The program team also had access to this platform which allowed us to address "Red Flags" raised by either party. Additional mentoring activities included group and individual mentoring sessions with the program team, that allowed the scholars to discuss their career aspirations. Topics included the various after completing a Ph.D., the benefits of completing a Ph.D., and the mechanics of how to apply for these programs.

Professional development sessions for the LSAMP Bridge to the Doctorate Scholars. These sessions usually lasted around 1 hour and included a presentation on a key professional development topic as well as extra time for the scholars to engage with each other and talk with leadership team members about any questions or concerns. Bridge to the Doctorate Professional Development topics were as follows: i) *Making the Most of Your Graduate Education*; ii) *Preparing an Individual Development Plan*; iii) *Managing Time and Stress as a Graduate Student*; iv) *Creating a Mentor Network*; v) *The Graduate Experience So Far: Discussing Accomplishments and Challenges with LSAMP Bridge to the Doctorate Scholars*; vi) *Exploring Library and AI Tools for STEM Researchers*; and vii) *Working Collaboratively with Your Advisor to Produce Outstanding Research*.

Methods

Study Design and Participants - This study employed a repeated cross-sectional survey design to examine changes over time in graduate students' experiences, perceptions, and outcomes related to STEM identity, mentoring, and institutional support. Surveys were administered at six time points across three academic years, from the beginning of Fall 2023 through the end of Spring 2025. The sample included graduate students enrolled in

STEM programs at a historically Black university and consisted of two groups: B2D (Bridges to the Doctorate) Scholars and non-B2D graduate students.

Across all survey waves, a total of 185 responses were collected, including 59 responses from B2D Scholars and 126 responses from non-B2D graduate students. Participation varied by time point, and students were not required to respond at every wave to be included in the study. As a result, the data were analyzed as repeated cross-sectional samples rather than as a fully longitudinal panel.

Data Collection Procedures - Surveys were administered online using a Qualtrics account controlled by the project leaders at the beginning and/or end of academic semesters. Invitations were distributed via institutional and departmental email lists, with targeted outreach to B2D Scholars facilitated by program leaders. Participation was voluntary, and respondents were informed that their responses would be used for research and program evaluation purposes. Although identifying items (e.g., name and email address) were included for program tracking, analytic datasets were de-identified by our external evaluation team during the analyses.

Survey Instrument and Constructs - The survey instrument was collaboratively designed by program leaders and the external evaluation team. Surveys were designed to capture multiple dimensions of graduate student development that are theoretically and empirically linked to persistence in STEM doctoral pathways. Items were drawn from established measures in the literature and adapted for the graduate STEM context. Across administrations, the survey retained a consistent set of core items to enable valid comparisons across time points. Survey items were organized into the following conceptual clusters:

Growth Mindset: Growth mindset was assessed using agreement-based items adapted from Dweck’s implicit theories of intelligence framework. Items measured beliefs about the malleability of intelligence, the role of effort in achievement, and responses to feedback (e.g., beliefs about whether intelligence can change, whether effort leads to improvement, and attitudes toward receiving feedback).

Resilience and Problem Solving: Resilience and problem-solving capacity were measured using items assessing coping, persistence, and confidence in handling challenges. These included statements related to managing difficult problems, remaining calm under pressure, identifying solutions, and handling unexpected situations.

STEM Academic Confidence: Academic confidence in STEM was assessed through items focused on understanding course material, interpreting experimental results, designing experiments, earning good grades, and completing coursework. These items captured students’ perceived competence and self-efficacy within their STEM programs.

Course Engagement and Career Aspirations: Engagement and future orientation were measured through items assessing effort in STEM courses, enjoyment of coursework, perceived relevance of academic performance to future careers, interest in STEM careers, and intentions to use STEM in professional pathways.

STEM Identity: STEM identity was assessed using a visual identity overlap item that asked students to select an image representing the overlap between their self-concept and their image of a STEM professional. Additional items assessed comfort interacting with STEM professionals and access to role models and family members in STEM careers.

Mentoring Network: Mentoring networks were assessed using a structured inventory capturing the number of mentors providing distinct forms of support, including intellectual feedback, intellectual community, sponsorship, access to opportunities, accountability, role modeling, professional development, emotional support, safe spaces, and financial guidance. Responses ranged from no mentors to a broad network of four or more mentors.

Interpersonal Relationships and Faculty Engagement: Students reported on peer and faculty relationships using agreement-based items assessing the quality and impact of relationships with other students and faculty. These included items related to friendship development, intellectual and personal growth, informal faculty interactions, and perceptions of faculty interest, availability, and teaching quality.

Perceptions of Belonging, Connection, and Engagement: Global perceptions of the STEM environment were measured through single-item indicators of satisfaction with support, feelings of isolation or inclusion, sense of connection, and engagement within the institutional STEM community.

Data Analysis

Analyses were conducted using SPSS statistical software. Two complementary analytic approaches were employed to examine change over time among B2D Scholars and to compare outcomes between B2D Scholars and non-B2D graduate students.

Pre–Post Change Analyses for B2D Scholars - To evaluate program-associated change, matched responses from B2D Scholars who completed surveys at both baseline (beginning of Fall 2023) and program endpoint (end of Spring 2025) were analyzed. Because survey items were measured using Likert-type response scales and the sample size of matched respondents was modest, all items were treated as ordinal variables. Consistent with best practices for ordinal repeated-measures data with small samples and non-normal distributions, Wilcoxon signed-rank tests were used to test for statistically significant pre–post differences.

For each survey item, three complementary indicators of change were calculated:

- Directional Movement (Percent Change Categories): The percentage of respondents whose scores declined, remained the same, or increased from pre- to post-measurement was computed.

- Mean-Level Change: Pre- and post-means were calculated for descriptive interpretation, along with a mean movement score representing average directional shift.
- Statistical Significance: Wilcoxon signed-rank Z statistics and associated p-values were calculated to assess whether observed pre–post changes differed significantly from zero.

Because analyses were conducted at the individual item level rather than aggregated scale scores, movement patterns were also examined across conceptual constructs (e.g., STEM identity, belonging) to determine which domains showed the greatest proportion of positive change. Construct-level comparisons were descriptive and based on aggregated percentages of items showing increases.

Between-Group Comparisons - Lastly, as a secondary analytic strategy, B2D Scholars' end-of-program responses were compared descriptively with those of non-B2D graduate students surveyed during the same period. These comparisons were conducted to contextualize B2D outcomes relative to institutional peers and to evaluate whether program participants exited with comparable or stronger levels of confidence, belonging, engagement, mentoring access, and STEM identity.

Because the primary analytic objective of between-group comparisons was interpretive benchmarking rather than hypothesis testing, these analyses focused on percentage distributions and relative differences rather than inferential statistical tests.

Significance Threshold - Statistical significance for Wilcoxon tests was evaluated at $\alpha = .05$. Given the exploratory nature of item-level analyses and the modest sample size of matched respondents, corrections for multiple comparisons were not applied. This approach prioritizes sensitivity to potential program-related changes while acknowledging that findings should be interpreted as exploratory rather than confirmatory.

Results

Construct-Level Change Patterns - Construct-level analyses examined the proportion of B2D Scholars whose responses improved from baseline (Fall 2023) to program endpoint (Spring 2025), along with average directional movement in item means within each construct. Overall, 46% of responses across all constructs showed improvement, with an average mean movement near zero (0.01), indicating modest but heterogeneous change patterns across domains. (See Table 1)

The strongest gains were observed in Problem Solving, where 72% of responses increased from pre to post and mean movement was positive (0.13), suggesting consistent improvement across items within this domain. Career Aspirations also demonstrated substantial positive movement, with 57% of responses improving, although the average mean movement was slightly negative (−0.13), indicating that while many individuals improved, the magnitude of change was small or uneven. Similarly, STEM Academic

Confidence showed improvement among half of respondents (50%), though mean movement was negative (−0.23), suggesting variability in direction or magnitude of individual item shifts.

Mid-range improvement was observed for Mentoring Network and Perceptions of Belonging and Engagement within the STEM Community, both of which showed 48% improvement rates. Notably, these constructs had positive mean movement values (0.12 and 0.19, respectively), indicating that when change occurred, it tended to be directionally positive. Resilience (45%) and Course Engagement (40%) demonstrated moderate levels of improvement with small positive mean shifts (both 0.02), reflecting relative stability with slight upward trends.

The lowest proportion of improvement was observed in Interpersonal Relationships and Faculty Engagement (37%) and STEM Identity (33%). Interpersonal and faculty relationship indicators showed a slightly negative mean movement (−0.08), suggesting small declines or stagnation for some respondents. In contrast, although STEM Identity had the lowest percentage of improved responses, it exhibited the largest positive mean movement (0.70), indicating that when gains occurred, they were substantial.

Taken together, these findings indicate that program-associated change was not uniform across domains. Skill-oriented constructs (e.g., problem solving) demonstrated the strongest improvement patterns, while relational and identity-related constructs showed slower or more variable change. This pattern is consistent with developmental research suggesting that cognitive and skill-based gains often precede shifts in identity and relational integration.

Table 1: Construct-Level Pre–Post Change Among B2D Scholars from Fall 2023 to Spring 2025

Row Labels	Average of % Improved (from pre- to post-)	Average of Mean Movement
Problem Solving	72%	0.13
Career Aspirations	57%	-0.13
STEM Academic Confidence	50%	-0.23
Mentoring Network	48%	0.12
Perceptions of Belonging and Engagement within the STEM Community	48%	0.19
Resilience	45%	0.02
Course Engagement	40%	0.02
Interpersonal Relationships and Faculty Engagement	37%	-0.08
STEM Identity	33%	0.70
Grand Total	**46%**	**0.01**

Item-Level Change: Highest and Lowest Movement - Item-level analyses identified substantial variability in pre–post change among B2D Scholars across constructs, indicating that program-related growth was domain-specific rather than uniform.

<u>Strongest Positive Movement</u>

The largest gains were observed in problem-solving, career commitment, mentoring access, and growth mindset beliefs. The strongest individual improvement occurred for the item “I can always manage to solve difficult problems if I try hard enough,” for which 90% of respondents showed improvement from baseline to endpoint. Similarly, high improvement rates (80%) were observed across several domains, including:

- interest in STEM careers
- intention to pursue STEM careers
- perceived access to opportunities through mentoring
- perceived sponsorship support
- appreciation of feedback
- confidence in generating solutions to problems

These findings indicate that the B2D program’s strongest measurable effects were concentrated in skill-based confidence, career commitment, and instrumental mentoring support rather than interpersonal or identity domains.

<u>Areas Showing the Least Improvement</u>

The lowest rates of improvement were concentrated in relational and social integration indicators. Several items showed improvement among only 10–22% of respondents, including:

- reactions to performance feedback
- satisfaction with informal faculty interaction opportunities
- satisfaction with student friendships
- confidence in earning good grades
- having role models
- perceiving value alignment with peers

One item, “Since coming to this university, I have developed close personal relationships with other students”, showed improvement for only 20% of respondents and demonstrated the largest negative mean movement (−0.82), indicating that social integration may have declined for some participants across time.

<u>Statistically Significant Changes</u>

Although most item-level changes were descriptive rather than statistically significant, four items demonstrated significant pre–post differences using Wilcoxon signed-rank tests ($\alpha = .05$):

- Belief intelligence can change (Growth Mindset) - Positive
- Liking STEM courses (Course Engagement) - Positive
- Developing close peer relationships (Relationships) - Negative
- Having peers willing to help (Support Climate) - Mixed but strong directional shift

These significant findings reinforce a pattern observed across descriptive results: cognitive beliefs and attitudes toward learning improved, whereas peer relationship indicators showed instability or decline.

Between-Group Exit Comparisons - At program completion, most outcomes were broadly similar between B2D Scholars and non-B2D graduate students; however, several meaningful differences emerged at the upper and lower ends of the distribution. These differences were concentrated primarily in beliefs about intelligence and personal change, perceived social support, and access to STEM-related social capital.

Higher Endorsement Trends Among B2D Scholars

Across several items, B2D Scholars reported higher levels of agreement than their non-B2D peers, particularly on statements reflecting perceptions of difference and selected academic challenges. For example, a larger proportion of B2D Scholars indicated that most students at the university hold values and attitudes different from their own (85.7% vs. 62.5%). B2D Scholars were also more likely to report that designing an experiment to test a question is difficult (28.6% vs. 6.3%), suggesting somewhat lower confidence in experimental design skills relative to peers. In addition, B2D Scholars showed higher endorsement of several belief statements related to ability and personal characteristics, including agreement that intelligence is something basic that cannot change much (42.9% vs. 18.8%) and that only a few people can truly be good at STEM because ability is innate (42.9% vs. 18.8%). These patterns indicate that the largest areas in which B2D Scholars differed from peers were concentrated not in motivation or effort orientation—which were high across both groups—but rather in underlying beliefs about ability and personal change.

Fixed-Trait Belief Differences

The most pronounced between-group differences were observed in items reflecting fixed-trait beliefs about intelligence and ability, where B2D Scholars consistently showed higher endorsement than their peers. The largest gap appeared for the statement "Truly smart people do not need to try hard," which 57.1% of B2D Scholars agreed with compared to 6.3% of non-B2D students. Similar patterns were evident for other fixed-belief indicators: 42.9% of B2D Scholars agreed that "you are a certain kind of person and there is not much that can be done to change that," compared with 6.3% of peers, and 42.9% agreed that intelligence is largely fixed, compared with 18.8% of non-B2D students. Likewise, 42.9% of B2D Scholars endorsed the statement that only a few people can truly be good at STEM because ability is innate, compared with 18.8% of their peers.

Taken together, these results indicate that the strongest between-group contrasts were concentrated in beliefs about the nature of ability rather than in indicators of motivation, effort, or career aspiration, which were uniformly high across both groups. This pattern suggests that although B2D Scholars demonstrated comparable academic engagement and commitment to STEM pathways, they were more likely than their peers to hold fixed-ability beliefs at program exit, highlighting a domain where developmental shifts may occur more gradually than skill- or motivation-related gains.

Interpretation of Between-Group Patterns

Overall, the largest observed gaps between groups were not found in motivation, effort, or academic persistence indicators—which were high for both groups—but rather in underlying beliefs about intelligence, personal change, and perceived similarity to peers. B2D Scholars tended to report stronger endorsement of fixed-trait statements, whereas non-B2D students showed slightly higher endorsement of growth-oriented beliefs and external support indicators such as parental encouragement and faculty developmental support.

At the same time, B2D Scholars did not exhibit weaker perceptions of peer support; in fact, they were less likely than peers to believe that fellow students would be unwilling to help them. This pattern suggests that although B2D Scholars may perceive themselves as different from peers, they do not necessarily experience lower perceived interpersonal support.

Discussion

The findings from this study describe patterns of change among B2D Scholars across several domains linked to persistence in graduate STEM training, including problem solving, mentoring access, academic confidence, belonging, and identity. The clearest gains were observed in areas related to skills and future orientation, particularly problem solving, career intentions, and access to mentoring resources.

In contrast, shifts in relational experiences and identity related measures were smaller and less consistent. This pattern is consistent with developmental perspectives indicating that increases in competence and confidence often occur before corresponding changes in self-concept or social integration. In practical terms, students may first strengthen their abilities and expectations for success before changes become evident in how they understand their place within an academic or professional community.

Comparisons between B2D Scholars and their peers provide additional context for understanding these patterns. By the end of the observation period, B2D Scholars reported levels of motivation, effort, and commitment to STEM careers that were similar to those of non B2D graduate students, indicating that participants exited the program with academic orientations comparable to those of the broader student population. The most notable differences between groups were found in beliefs about intelligence and personal change. B2D Scholars more often endorsed statements reflecting fixed views of ability, whereas non B2D students more frequently endorsed growth-oriented beliefs and certain external support indicators such as parental encouragement and faculty developmental support. At the same time, B2D Scholars did not report weaker perceptions of peer support. In some cases, they were less likely than peers to report that other students would be unwilling to help them, suggesting that perceiving oneself as different from others does not necessarily coincide with feeling unsupported by them.

When evaluating research on similar programs it is noted that bridge programs come in various formats and with varying goals. For example, Stassun et al., focuses on findings from a master's to Ph.D. bridge program/partnership for a STEM program between an HBCU and a local PWI that is considered R1[10]. Even though the goals are separate, the paper highlights the need to assist students as they transition to new and more challenging settings. Which can come inf the form of a new institution, higher degree (*i.e.,* going from a masters to a Ph.D.), or both. Stassun *et al.,* report a high level of retention (91%) which is similar to our results. Though no numerical data was presented in their paper, it appears that participants in their bridge program showed high submission and awarding rates of national competitive fellowships. This is a difference compared to the program described here. The current study and the work by Stassun et al., both highlight the importance of building community and connection with other students as well as mentors and faculty.

Gale *et al.,* released an extensive report on the Sloan University Centers of Exemplary Mentoring Program. The report outlines programs with similar goals as the Bridge to Doctorate program described in this paper. While their report included a larger sample than the current paper, the current Bridges to the Doctorate intervention showed higher completion and graduation rates. Similar findings between the current study and the work by Gale and McGuire, include the importance of building community within students. Results from both studies highlight quotes from participants, highlight the impact of meeting people through the respective programs. Such meetings helped participants feel affirmed and supported[11]. This further supports the importance of support outside of traditional monetary support.

Conclusion

The purpose of this program was to prepare a cohort of 12 LSAMP Bridge to the Doctorate Fellows to persist in STEM Ph.D. programs at North Carolina A&T State University. The need for programs like this stem from the well documented shortage of individuals who will obtain graduate degrees in STEM. The BD program at North Carolina A&T State University, was designed based on the best practices from numerous graduate STEM mentoring programs as well as a theoretical framework that considers social cognitive career theory, self-efficacy, and STEM research identity. Results show the importance of mentoring, professional development, and building community for individuals who are pursuing advanced degrees. These supports are in addition to financial resources allocated for students. Steps outlined in this paper are applicable to institutions of various types and sizes, showing the feasibility of implementing an effective program that will support the achievement of Ph.D.'s in STEM fields.

References

[1]

“Ronald E. McNair Postbaccalaureate Achievement Program,” Feb. 26, 2026. Available: https://www.ed.gov/grants-and-programs/grants-higher-education/federal-trio-programs/ronald-e-mcnair-postbaccalaureate-achievement-program

[2]

H. B. Carlone and A. Johnson, “Understanding the science experiences of successful women of color: Science identity as an analytic lens,” vol. 44, no. 8, pp. 1187–1218, 2007.

[3]

R. W. Lent, S. D. Brown, and K. C. Larkin, “Self-efficacy in the prediction of academic performance and perceived career options.,” vol. 33, no. 3, p. 265, 1986.

[4]

M. T. Nietzel, “HBCUs Lead Nation In Black Baccalaureates Who Later Earn Doctoral Degrees,” Aug. 19, 2022. Available: https://www.forbes.com/sites/michaeltnietzel/2022/08/19/hbcus-are-nations-leading-institutions-for-black-baccalaureate-graduates-who-later-earn-a-phd/. [Accessed: Jan. 23, 2026]

[5]

Harton *et al.*, “New U-RISE and MARC Funding Opportunities and Upcoming Webinar,” Apr. 09, 2024. Available: https://www.nigms.nih.gov/loop/2024/04/new-u-rise-and-marc-funding-opportunities-and-upcoming-webinar

[6]

“Accelerate to Industry+ (A2i+).” Available: https://grad.ncsu.edu/professional-development/careers-outside-of-academia/a2i/

[7]

S. Deitz and C. Freyman, “The state of US science and engineering 2024,” vol. 46, 2024.

[8]

K. I. Maton *et al.*, “Outcomes and processes in the Meyerhoff Scholars Program: STEM PhD completion, sense of community, perceived program benefit, science identity, and research self-efficacy,” vol. 15, no. 3, p. ar48, 2016.

[9]

A. Bandura, M. Rumsey, C. Walker, and J. Harris, “Regulative function of perceived self-efficacy,” pp. 261–271, 1994.

[10]

  Wondwossen and Wayna, “The science behind HBCU success,” September 202. Available: https://www.nsf.gov/science-matters/science-behind-hbcu-success. [Accessed: Jan. 22, 2026]

[11]

“GEM Fellowship Program.” Available: https://www.gemfellowship.org/gem-fellowship-program/

[12]

C. Cosentino, “Evaluation of the Louis Stokes Alliances for Minority Participation (LSAMP) Bridge to the Doctorate Initiative”, Available: https://www.mathematica.org/projects/lsamp-bridge-to-the-doctorate-fellowship

[13]

J. Kent, “Ph.D. Completion Project.” Available: https://cgsnet.org/data-insights/access-and-inclusion/degree-completion/ph-d-completion-project

[14]

G. Keivan, Stassun, A. Burger, and S. E. Lange, “The Fisk-Vanderbilt Masters-to-PhD Bridge Program: A Model for Broadening Participation of Underrepresented Groups in the Physical Sciences through Effective Partnerships with Minority-Serving Institutions.”

[15]

“Promising Practices: Mentoring and Advising.” Available: https://www.asgraduate.pitt.edu/sites/default/files/CGS%20Ph.D.%20Completion%20Project.pdf

[16]

T. Gale and D. Mcguire, “An Evaluation of the Sloan University Centers of Exemplary Mentoring Program.”

[17]

N. A. of S. Medicine Engineering, and, *The Science of Effective Mentorship in STEMM*. Washington, DC: The National Academies Press, 2019. doi: 10.17226/25568. Available: https://nap.nationalacademies.org/catalog/25568/the-science-of-effective-mentorship-in-stemm

[18]

N. Josemans, “Fast Facts Report for the Ronald E. McNair Postbaccalaureate Achievement Program: 2019-20,” Aug. 2023.