2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #54034

Forging the Engineering Pipeline: Integrating Research and Teaching to Boost Retention

Dr. Lara Perez-Felkner, Florida A&M University - Florida State University

Lara Perez-Felkner is a Professor of Higher Education and Sociology and Faculty Fellow in the Graduate School at Florida State University (FSU).

Subramanian Ramakrishnan, Florida A&M University - Florida State University
Jamel Ali, Florida A&M University - Florida State University

Forging the Engineering Pipeline:

Integrating Research and Teaching to Boost Retention

The post-COVID educational landscape has presented a critical shift in student behavior, characterized largely by the disruption of established norms for academic help-seeking. Historically, engineering retention relied on students engaging with faculty office hours, learning assistants, and peer networks to master complex material. However, the increased reliance on remote instruction and the rapid advent of generative AI tools have cultivated a mindset of isolated learning. Recent scholarship suggests that when artificial intelligence substitutes human interaction in higher education, it incurs a "cost of loneliness" that is detrimental to student success and retention [1].

This Work-In-Progress paper reports on early evidence from a targeted infusion project designed to counter these trends within a Chemical and Biomedical Engineering program. The project leverages strategic investments in structured, in-person tutoring and active learning to rebuild a campus-based learning community. We conceptualize these patterns through the lens of capital theory. In this paper, capital refers to the social, navigational, intellectual, and symbolic resources that enable students to access opportunity structures within engineering education [2]. When students substitute isolated digital problem-solving for relational engagement, they may gain short-term technical solutions but fail to accumulate the forms of capital necessary for persistence.

This approach is particularly critical for guiding students through advanced mathematical concepts—specifically differential equation modeling—that serve as significant obstacles to progression. Despite students' initial interest in scientific applications, limitations in pre-college mathematics preparation, often associated with the schools they attended prior to transferring, create early bottlenecks in the major. By prioritizing human-centered supports over solitary online searches, this intervention aims to restore the "navigational capital" essential for persisting in a rigorous engineering curriculum. The findings reported here represent preliminary outcomes from the first year of implementation (2024–2025 cohort) of a multi-tiered intervention. Ongoing data collection includes longitudinal retention metrics, student perception surveys, and comparative cohort analyses.

Problem Statement: Addressing Student Isolation

The shift toward isolated learning poses a disproportionate risk to community college transfer students. These students often arrive with less preparation in advanced mathematics and limited experience navigating the complex, resource-rich environment of a large research university. Evaluations of the current program highlight that recruitment challenges are frequently tied to student preparation in mathematics, specifically regarding concepts like differential equations which are foundational to chemical engineering analysis. Without intentional support, these students are the demographic most likely to fend for themselves, relying on digital proxies rather than integrating into the departmental ecosystem. This isolation effectively severs them from the social networks vital for survival in engineering. Mon-Williams and Blajos [3] emphasize that transfer students require programmatic approaches that go beyond simple academic advising; they need intentional structures to bridge the gap between their prior institutions and the university's professional norms.

Theoretical Framework

This intervention is grounded in the convergence of social capital and science capital frameworks. We draw on Bourdieu's foundational definition of capital as the aggregate of actual or potential resources linked to the possession of a durable network of relationships [2]. In the context of racial and ethnic minority youth, Stanton-Salazar [4] expands this to highlight how institutional agents, such as tutors and faculty, must act as bridges to decode the "hidden curriculum" of the university. Building on this, we view "science capital" not just as knowledge, but as the dispositions, behaviors, and contacts that allow a student to feel they belong in STEM [5]. Our model posits that academic social capital gained through tutoring is a prerequisite for developing the professional science capital necessary for a long-term engineering career.

Description of the Intervention

The project implements a multi-tiered ecosystem designed to scaffold students from academic struggle to professional confidence. REU participants were selected through a competitive application emphasizing academic potential, interest in research, and alignment with faculty projects. Targeted outreach efforts were made to first-generation and transfer students, and selection procedures were reviewed for equity considerations. Community college transfers are intentionally embedded in research teams that include continuing students, thereby accelerating relational capital formation and mitigating the social discontinuity often experienced during transfer transitions.

Our engagement with regional community colleges extends the capital-building framework upstream of formal matriculation. By inviting community college students into summer REU experiences, outreach modules (e.g., chocolate 3D printing, COMSOL demonstrations), and laboratory immersion activities, we begin cultivating science capital prior to transfer. These early exposures function as anticipatory socialization, allowing students to enter the university not as peripheral outsiders but as emerging members of the engineering community. In Year 2, three community college students participated in the REU; two subsequently matriculated into the FAMU-FSU College of Engineering (Fall 2025). Additionally, two community college transfer students secured NASA internships, reinforcing both vertical mobility and professional capital acquisition.

Tier 1: Rebuilding Community through Structured Tutoring. The first tier leverages strategic investment in structured, in-person tutoring for gateway courses. Evaluation feedback suggests that introductory learning options, such as "Intro to Engineering," benefit significantly from mathematics-intensive modules designed to support transitions into the major. Strengthening pre-transfer mathematics preparation reduces attrition risk upon entry, particularly in differential equation–intensive courses. Unlike passive study halls, these sessions are designed as deliberate interventions to rebuild a learning community. By encouraging students to choose collaborative problem-solving over solitary AI-assisted work, we cultivate the peer-to-peer networks that provide emotional and academic support [1, 4]. Structured tutoring is intentionally designed to build *navigational capital* (knowing how to access institutional resources), *social capital* (peer and mentor networks), and *help-seeking capital*—the disposition to mobilize these resources in moments of academic strain. Table 1 lists the student contact hours and number of students in each session.

Table 1. Student Tutoring Engagement Per Course

Course	Student Contact Hours	# Students Attended
ECH 3301 Process Analysis and Design	121.50	17
ECH 3024 Mass and Energy Balances II	53	12
BME 4211 Biomechanics	42.5	9
MAC 2312 Calculus with Analytic Geometry	37.75	7
MAP 2302 Ordinary Differential Equations	30.5	3
PHY 2048C General Physics A	24.83	8
ECH 3023 Mass and Energy Balances I	24.5	12
BME 3009 Introduction to Biomedical Engineering	16	4
BME 3100 Biomaterials	16	9
EGN 3442 Statistical Topics in Engineering	14.75	3

Tier 2: Active Learning in Laboratory Units. Targeted tutoring efforts are complemented by a second tier of collaborative, active-learning laboratory units. Building on the team's prior NSF-funded curricular innovations (2016–2020), we have refined a suite of modules that tangibly connect abstract concepts to physical reality, forcing students out of theoretical isolation and into collaborative experimentation. These laboratory modules cultivate *intellectual capital* by linking mathematical abstraction to material phenomena, while simultaneously expanding *relational capital* through structured collaboration. The repeated requirement to interpret data collectively reinforces disciplinary norms, further increasing students' science capital and self-reported confidence.

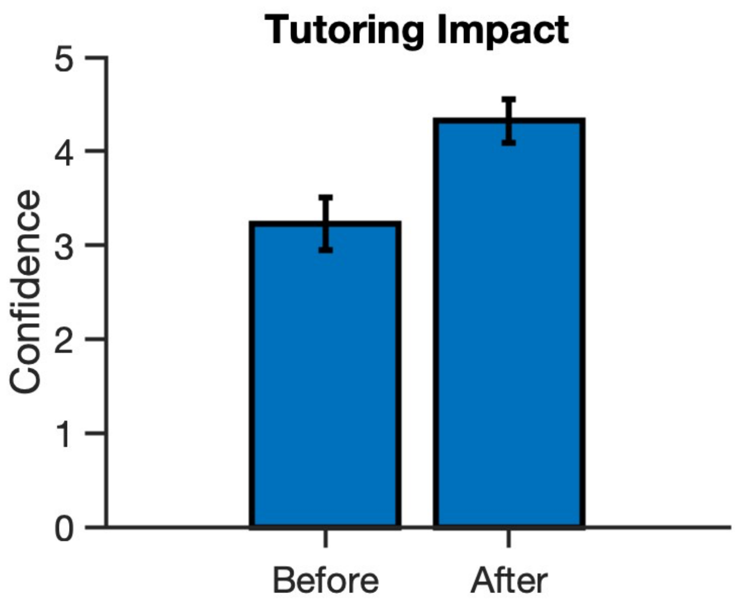

Fig. 2 – Students self-reported confidence boost in their core engineering coursework.

For example, in the introductory *First-Year Engineering Lab*, students engage in a "Biofuels Production" module. This early exposure provides a low-stakes, high-engagement entry point where students must work in teams to navigate the chemical processes, fostering early peer bonding. As students progress to the *Unit Operations Laboratory*, they encounter the "Shear Genius" experiments—a sophisticated rheology unit that utilizes chocolate tempering and polymer slime to teach complex fluid dynamics and crystallization concepts.

Further up the curriculum in *Thermodynamics* (a traditional "weed-out" course), we utilize Differential Scanning Calorimetry (DSC) equipment procured through grant funding. Rather than viewing thermodynamics as purely mathematical, students use DSC to visualize phase transitions, grounding the abstract differential equations in observable data. These modules are not merely technical exercises; they are social events where data interpretation requires dialogue, debate, and consensus-building, directly countering the "lonely learner" phenomenon.

Tier 3: The REU as a High-Impact Practice. The capstone of this model is a summer Research Experience for Undergraduates (REU), which recently supported a cohort of 23 participating students. The REU tier is explicitly structured as an advanced capital-building mechanism. Students accumulate *science capital* through authentic research participation, *symbolic capital* through affiliation with competitive programs, and *professional capital* through mentorship toward national fellowships and graduate pathways. Consistent with findings by Fluker, Perez-Felkner, and McCoy [6], we find that this intensive mentorship is highly effective in developing students' engineering identity.

The program explicitly mentors students towards prestigious graduate funding opportunities, such as the NSF Graduate Research Fellowship Program (GRFP). Despite increased competition and funding constraints at the federal level, this mentorship aims to equip students with the "prestige and networking benefits" associated with such awards, fostering structured pathways to professional careers by validating the student's role as a creator of knowledge. While the REU is inherently limited in scale, the program's design treats the REU as an aspirational apex rather than a universal requirement. Core capital-building mechanisms (tutoring and labs) are embedded within required coursework to ensure broad reach. Future work will explore course-based undergraduate research experiences as a scalable alternative.

Tier	Intervention Activity	Targeted Coursework / Gap	Mechanism of Action	Capital Developed
1	**Structured In-Person Tutoring**	Gateway Math & *Intro to Engineering*	Forces "friction" against solitary AI use; builds peer help-seeking habits.	**Navigational & Social:** Learning *who* to ask and *how* to navigate the department.
2	**Active Learning Modules**	*Thermodynamics*, *Unit Ops*, *First-Year Lab*	Connects abstract differential equations to physical phenomena (e.g., DSC, Rheology).	**Intellectual & Social:** collaborative data interpretation requires team dialogue.
3	**REU & Fellowship Mentorship**	Summer Research & Senior Design	Mentorship toward NSF GRFP and graduate school pathways.	**Science & Symbolic:** Validating the student as a "scholar" and creator of knowledge.

Preliminary Discussion and Future Work

Synthesizing Social and Science Capital. The preliminary outcomes of this targeted infusion project suggest that retention in rigorous engineering disciplines is not solely a matter of academic ability, but of social integration. By structuring the intervention as a pipeline—moving from the low-stakes social environment of peer tutoring to the high-stakes professional environment of the REU—we observe a "scaffolding" of capital. The initial data indicates that the structured tutoring component functions as a "thaw" for help-seeking behaviors; students who engage in these human-centered spaces are breaking the habit of solitary reliance on digital tools. This validates Stanton-Salazar's [4] framework, where institutional agents (tutors) successfully decode the hidden curriculum for transfer students, transforming the university from a hostile environment into a navigable network.

The Role of Tangible Engagement. Furthermore, the integration of active learning modules like the "Shear Genius" rheology experiments and biofuels production serves a dual purpose. Beyond the acquisition of technical knowledge, these modules force students into "communities of practice." In the post-COVID era, where students often view coursework as a transactional exchange of data, these hands-on labs re-establish the classroom as a social site. By grounding abstract differential equations in physical phenomena (e.g., observing phase transitions via DSC), the curriculum validates the students' interest in *application* while bridging the gap in their mathematical preparation. This is particularly crucial for the transfer student demographic, whose prior institutions may not have provided the same density of advanced instrumentation.

Mentorship as Identity Formation. The most profound shifts, however, are observed within the REU cohort. The explicit mentorship toward high-prestige outcomes (such as the NSF Graduate Research Fellowship Program) functions as a mechanism for identity construction. As noted in recent project evaluations [5], even as federal funding landscapes tighten, the act of preparing a competitive fellowship application forces students to articulate a "scholar" identity. This process—supported by the "science capital" of faculty mentors—effectively counters the imposter syndrome often reported by underrepresented minorities in engineering [6]. By positioning these students as creators of knowledge rather than passive consumers of curriculum, the program creates an "engineering resilience" that persists beyond the summer experience [7].

Future Directions and Sustainability. As the project matures, the focus will shift toward the long-term sustainability of these human-centered interventions. The team is currently exploring how to institutionalize the "math-intensive" bridge modules within the standard *Introduction to Engineering* sequence to permanently address the pre-college preparation gaps observed in transfer cohorts. Additionally, with the reduction in available federal fellowship slots, future work will involve identifying and curating a broader portfolio of external funding opportunities to ensure the pipeline to graduate school remains robust. Longitudinal analysis will track the 2024-2025 cohort to quantify the specific impact of these interventions on time-to-degree and graduation rates, providing a replicable model for other institutions seeking to prioritize the "human in the loop" in an increasingly automated age.

Our engagement with regional community colleges serves as both a recruitment and capital-alignment strategy. Rather than treating transfer students as late entrants into the engineering ecosystem, we invite them into research and laboratory experiences prior to matriculation. Participation in REU programs, exposure to applied modeling demonstrations (e.g., COMSOL simulations, 3D printing modules), and early visibility into federal laboratory pathways collectively build anticipatory science capital. As a result, transfer students enter the university with established relational networks, technical exposure, and professional aspirations, reducing the discontinuity typically associated with transfer transitions.

References

[1] J. Rudolph, S. Tan, and S. Tan, "When artificial intelligence substitutes humans in higher education: the cost of loneliness, student success, and retention," *Tertiary Education and Management*, vol. 30, no. 1, pp. 83-97, 2024.

[2] P. Bourdieu, "The Forms of Capital," in *Handbook of Theory and Research for the Sociology of Education*, J. G. Richardson, Ed. New York: Greenwood Press, 1986, pp. 241-258.

[3] C. B. H. Mon-Williams and S. D. Blajos, "Supporting the Transfer Student in Engineering: A Programmatic Approach," in *Proc. ASEE Annual Conference & Exposition*, 2018, pp. 23.456.1-23.456.12.

[4] R. Stanton-Salazar, "A Social Capital Framework for Understanding the Socialization of Racial Minority Children and Youths," *Harvard Educational Review*, vol. 67, no. 1, pp. 1-40, 1997.

[5] E. J. Theobald et al., "Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math," *Proceedings of the National Academy of Sciences*, vol. 117, no. 12, pp. 6476-6483, 2020.

[6] C. Fluker, L. Perez-Felkner, and K. McCoy, "Students' Perceptions of an REU Summer Internship Program and their Engineering Identity Development: An Equity-Centered Analysis," in *Proc. ASEE Annual Conference & Exposition*, 2022.

[8] L. Perez-Felkner, C. Shore, T. Dickens, and M. D. Yang, "Engineering Resilience through Research Mentorship: Manufacturing Pathways to Careers," in *Proc. ASEE Annual Conference & Exposition*, 2020, doi: 10.18260/1-2–34557.