Cultivating Neuroadaptive Learning Ecosystems through AI-Powered Personalized Learning

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Abstract

Engineering undergraduate programs face persistent challenges in supporting the academic success and inclusion of neurodiverse learners. Conventional engineering instruction often emphasizes uniform pacing and assessment modalities that align poorly with diverse cognitive profiles, contributing to attrition and disengagement. This NSF IUSE project establishes a cross-institutional initiative to design, implement, and scale AI-enabled neuroadaptive learning ecosystems that support personalized learning pathways across engineering and mathematics while fostering self-regulated learning and inclusive instructional cultures. In addition to transforming classroom practice, the project integrates AI-augmented academic advising and coaching to provide continuous, human-in-the-loop support beyond the classroom. In its first year, the project focused on building conceptual frameworks, engaging engineering and mathematics faculty in neuroinclusive pedagogy, and developing prototype architectures for AI-mediated learning and advising support.

Introduction and Motivation

Undergraduate engineering instruction has historically assumed homogenous learning preferences and trajectories, leaving learners with cognitive differences, including Attention Deficit Hyperactivity Disorder (ADHD), autism spectrum traits, and language processing variability, at a disadvantage relative to their peers. Engineering curricula often rely on fast-paced lectures, high-stakes assessments, and rigid problem sets, limiting accessibility for a significant portion of the student population. Research underscores that systemic instructional barriers are primary contributors to inequitable learning outcomes [1].

Alongside increased awareness of neurodiversity in higher education, recent public and academic discourse has begun to question the legitimacy, rigor, and scalability of accommodation-based models [2,3]. Some commentary frames disability supports as potentially undermining academic standards, casting accommodations as advantages rather than equity mechanisms. These debates highlight a structural challenge: traditional accommodation systems are reactive and administratively complex, often positioning inclusion as an exception rather than an integral component of course design. Such framing risks re-marginalizing neurodiverse learners at a time when broad participation in engineering is increasingly important.

The convergence of inclusive pedagogy and artificial intelligence (AI) offers a different pathway forward. Rather than retrofitting courses through individualized exceptions, AI-enabled personalization is embedded into the instructional design. When learning pathways, feedback, pacing, and support are designed for *all* students, inclusion becomes a property of the system, countering deficit-oriented narratives. In this framework, AI does not replace human judgment or pedagogy. Instead, it supports instructors and advisors in implementing neuroinclusive practices at scale, moving beyond a compliance-oriented model toward one in which diversity of cognition is anticipated, supported, and valued.

Conceptual Framework

This project is grounded in a strength-based conception of neurodiversity and adopts human-centered artificial intelligence to construct neuroadaptive learning ecosystems in engineering education. Neurodiverse students bring distinctive cognitive traits, including differences in attention, sensory processing, communication, and executive function, that shape how they engage with learning. These traits can present genuine challenges in traditional learning environments, but they also represent valuable ways of thinking that are often underutilized [1]. Within this framework, the primary locus of adaptation shifts from the individual to the educational system. Instructional practices, institutional structures, and support mechanisms are designed to work with learner traits, adjusting to diverse ways of processing information, pacing work, and engaging with content.

Human-centered AI provides a mechanism for enacting this shift at scale. Advances in generative and adaptive AI systems make it possible to respond dynamically to learner input, pacing, and goals while preserving human oversight and pedagogical intent [4,5]. In this project, AI is not positioned as an autonomous tutor or decision-maker. Instead, it functions as an augmentative layer that supports instructors, advisors, tutors, and students in making learning pathways more visible and responsive to student needs. For example, AI tools can help generate alternative explanations of core concepts, suggest structured study plans, or surface patterns in student engagement that inform advising conversations. Human judgment remains central; AI operates as a scaffold for reflection, feedback, and alignment between learner needs and institutional structures.

Neuroadaptive learning ecosystems emerge at the intersection of these commitments. An ecosystem, as we use the term, is not a single tool or platform, but a coordinated network of instructional practices, advising structures, and support mechanisms that adapt over time to learner engagement and context. Personalization is embedded within teaching, tutoring, and advising rather than delivered through exceptional or stigmatizing interventions. Adaptation occurs across multiple layers: within courses through flexible content and assessment pathways; across the curriculum through targeted redesign of bottleneck courses, particularly in mathematics; and beyond the classroom through AI-augmented advising and coaching that make self-regulated learning processes more explicit and actionable.

Project Description and Methodology

This project is a multi-institutional effort that builds directly on a prior NSF RED initiative that established a strength-based model for neuroinclusive teaching in engineering. That earlier work demonstrated that culture change and instructional redesign grounded in a strengths-based view of neurodiversity can reshape faculty practice and student experience. The present project extends that foundation by integrating artificial intelligence as a core enabling technology. Two large public research universities serve as coordinated testbeds, allowing the project to examine how a shared framework is enacted across distinct institutional contexts while maintaining a common design language and implementation architecture.

The project advances a neuroadaptive learning ecosystem through two tightly coupled implementation domains: (1) transformation of teaching and learning in high-leverage courses, with a particular emphasis on early-sequence mathematics, and (2) student support through AI-augmented advising and academic coaching. Research and evaluation are embedded throughout both domains to guide design, document enactment, and inform continuous improvement.

Domain 1: Neuroadaptive Teaching in Engineering and Mathematics

The first domain advances the neuroinclusive teaching model developed under the prior RED grant [6] by integrating AI practices and tools into the redesign of high-leverage engineering and mathematics courses. The earlier work articulated course design principles for neuroinclusive engineering instruction, including transparent expectations, flexible demonstration of mastery, structured scaffolding of complex tasks, multiple modes of explanation, and explicit support for self-regulated learning. In this project, faculty learning communities adopt these principles as the foundation for course redesign and use AI tools to help implement them consistently and at scale.

Implementation builds on a faculty learning community model. Participating instructors receive access to enterprise generative AI tools (e.g., institutionally licensed large language model platforms) and engage in structured redesign of course components. AI is used in three primary ways: First, as a design assistant for instructional materials. Faculty use AI to generate alternative explanations of core concepts, produce multiple versions of practice problems at varied levels of difficulty, refine assignment prompts for clarity, and create structured, stepwise solution guides. Second, as a scaffold for student engagement. Course-specific chatbots are configured with explicit prompting structures (e.g., "show only the first step," "ask a follow-up question before giving a full solution," "require the student to state assumptions"). These constraints are designed to discourage answer substitution and instead support procedural fluency and conceptual reasoning. Third, as a reflective partner in course improvement. AI tools are used to review grading rubrics for ambiguity, generate in-class formative assessments, and assist in creating interactive visualizations. In all cases, faculty retain responsibility for validation and oversight.

Across both institutions, this work is coordinated through shared design principles, joint faculty convenings, and common artifacts. The multi-institution structure enables the project to examine how neuroadaptive teaching practices translate across different cultures and organizational contexts, while maintaining coherence in values and implementation logic.

Domain 2: AI-Augmented Advising and Academic Coaching

The second domain extends neuroadaptive design beyond the classroom through two complementary efforts. The first effort centers on the development of SAGE (Student-focused Adaptive Guidance Engine), a course-specific intelligent tutoring framework designed to enforce instructor-regulated learning in foundational STEM courses. SAGE is implemented using an enterprise large language model API layered with a Retrieval-Augmented Generation (RAG) architecture and an instructor-defined policy gatekeeping layer that filters outputs based on curated course materials and sequencing rules. Development is led by faculty and graduate researchers in collaboration with instructional staff, who define learning progressions, configure access controls, and iteratively test system behavior.

Unlike general-purpose chatbots that default to complete answers, SAGE is structured to provide scaffolded, stepwise guidance aligned with instructor-defined objectives. Rather than generating full solutions, it releases hints incrementally, prompts students to articulate assumptions, and requires intermediate reasoning before advancing. SAGE operationalizes SRL processes, including goal setting, planning, monitoring, and reflection, by making problem-solving pathways explicit while preserving active cognitive engagement.

The second effort focuses on embedding institutionally licensed LLM tools into advising, tutoring, and peer-mentoring practices. Advisors and mentors use these systems to support structured planning, reflective dialogue, and decision-making during advising interactions, while students use them to draft academic plans, rehearse decisions, and externalize study strategies prior to meetings. AI does not replace relational advising; it functions as a shared scaffold that enhances consistency, responsiveness, and personalization within a human-in-the-loop model.

Although these efforts originate in different contexts, one course-embedded and one co-curricular, and are advancing in parallel at the two institutions, they are designed to inform one another. Over time, they will converge into a coherent neuroadaptive support layer that spans classroom and advising environments, reinforcing self-regulated learning as a visible and practiced habit across the student experience.

Ethical Considerations

The integration of AI in neuroadaptive learning ecosystems raises important ethical questions that the project addresses proactively. Data privacy is addressed through access to secure platforms such as Amplify and enterprise LLM licenses. Algorithmic bias is another risk; AI models trained on non-diverse datasets could perpetuate inequities, so the project incorporates bias audits and diverse training data. Over-reliance on AI might diminish human interaction, but the human-in-the-loop design ensures educators retain oversight. Accessibility is prioritized to avoid excluding students without reliable technology access. Ongoing ethical reviews by an institutional review board guide implementation, ensuring that personalization enhances equity without compromising rigor or autonomy.

Embedded Research and Evaluation

Research and evaluation are embedded across both domains and focus on three areas: (1) student learning and self-regulated learning (SRL), (2) faculty and student attitudes toward AI, and (3) cultural change.

First, student outcomes are examined in redesigned courses using course performance metrics (e.g., exam scores, DFW rates, progression in gateway mathematics), de-identified AI interaction data, and validated SRL measures administered longitudinally. These data allow us to assess whether AI-supported scaffolding strengthens foundational skill development and adaptive learning behaviors over time. Second, surveys and focus groups document faculty and student attitudes toward AI integration, including perceptions of rigor, autonomy, workload, and instructional value. We examine whether structured AI use influences students' confidence, clarity of expectations, and sense of belonging, as well as faculty perceptions of personalization at scale. Third, qualitative interviews and faculty learning community artifacts are used to examine cultural and organizational change, including shifts in discourse and practice related to neuroinclusivity and AI-supported instruction.

Mixed-methods findings inform iterative refinement and cross-institutional comparison of neuroadaptive implementation. This integrated design positions neuroadaptive learning ecosystems as a scalable model for aligning rigor, personalization, and inclusion in engineering education.

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References

[1] Clouder, L., Karakuş, M., Cinotti, A., Ferreyra, M. V., Amador Fierros, G., & Rojo, P. (2020). *Neurodiversity in higher education: A narrative synthesis*. Higher Education, 80(4), 757–778.

[2] Horowitch, R. (2025). *Accommodation Nation: America's Colleges Have an Extra-Time-on-Tests Problem. The Atlantic*, January 2026 Issue. [online] Available: https://www.theatlantic.com/magazine/2026/01/elite-university-student-accommodation/684946/

[3] Washington Post Editorial Board. (2026, January 2). *America's Fragile Future Elite Will Meet the Real World Eventually: A Shocking Number of Students at Top Universities Claim Dubious Disabilities — and Get Advantages.* The Washington Post. [Online]. Available: https://www.washingtonpost.com/opinions/2026/01/02/university-disability-claims-adhd-advantages/.

[4] M. Bond, H. Khosravi, M. de Laat, N. Bergdahl, V. Negrea, E. Oxley, P. Pham, S. W. Chong, and G. Siemens, "A meta-systematic review of artificial intelligence in higher education: A call for increased ethics, collaboration, and rigour," *International Journal of Educational Technology in Higher Education*, vol. 21, no. 1, pp. 4–41, 2024.

[5] D. T. K. Ng, C. W. Tan, and J. K. L. Leung, "Empowering student self-regulated learning and science education through ChatGPT: A pioneering pilot study," *British Journal of Educational Technology*, vol. 55, no. 4, pp. 1328–1353, 2024.

[6] Chrysochoou, M., & Zaghi, A. E., & Syharat, C. M., & Motaref, S., & Jang, S., & Bagtzoglou, A., & Wakeman, C. A. (2021, July), *Redesigning Engineering Education for Neurodiversity: New Standards for Inclusive Courses* Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference. 10.18260/1-2--37647