From Body of Knowledge to Modular Implementation: A Faculty Learning Community Model for Graduate Chemical Engineering Reform

Dr. Mary E. Besterfield-Sacre, University of Pittsburgh

Dr. Mary Besterfield-Sacre is Senior Associate Dean for Academic Affairs and Nickolas A. DeCecco Professor in Industrial Engineering at the University of Pittsburgh. She is the Founding Director for the Engineering Education Research Center (EERC).

Dr. April Dukes, University of Pittsburgh

Dr. April Dukes is the Faculty and Future Faculty Program Director for the Engineering Educational Research Center (EERC) and the Institutional Co-leader for Pitt-CIRTL at the University of Pittsburgh. Dr. Dukes' current research and professional development efforts focus on two critical areas shaping the future of higher education. She serves as Senior Staff on a major National Science Foundation (NSF) project to create and validate a Personalized Learning Model (PLM) for STEM graduate education. This work is dedicated to increasing inclusivity by replacing "one-size-fits-all" training with flexible, student-centered pathways tailored to individual backgrounds and career goals. Additionally, she leads research into effective strategies for implementing the ethical and responsible use of generative AI in teaching, learning, and faculty professional development.

Prof. Susan K Fullerton Shirey, University of Pittsburgh

Susan Fullerton is an Associate Professor, Bicentennial Board of Visitors Faculty Fellow, and Vice Chair for Graduate Education in the Department of Chemical and Petroleum Engineering at the University of Pittsburgh. She earned her Ph.D. in Chemical Engineering at Penn State in 2009, and joined the Department of Electrical Engineering at the University of Notre Dame as a Research Assistant Professor. In 2015 she established the Nanoionics and Electronics Lab at Pitt as an Assistant Professor, and was promoted to Associate Professor with tenure in 2020. Fullerton's work has been recognized by an NSF CAREER award, an Alfred P. Sloan Fellowship, a Marion Milligan Mason award for women in the chemical sciences from AAAS, and a Ralph E. Powe Jr. Faculty Award from ORAU. For her teaching, Fullerton was awarded the 2018 James Pommersheim Award for Excellence in Teaching in Chemical Engineering at Pitt. For more information: http://fullertonlab.pitt.edu/

Dr. Gary Lichtenstein, Quality Evaluation Designs

Gary Lichtenstein, Ed.D., is founder and principal of Quality Evaluation Designs, specializing in education research and program evaluation.

Dr. Götz Veser, University of Pittsburgh
Ms. Abigail T Stephan, Clemson University

Dr. Abigail (Abby) Stephan is a Research Assistant Professor in the Department of Psychology and an affiliated faculty member at the Institute for Engaged Aging at Clemson University in South Carolina. Her research explores a) the influence of intergenerational relationships in family, community, and educational contexts on learning, development, and well-being across the lifespan and b) examines social and psychological factors that promote healthy aging. In addition to taking an ecological, systems-oriented perspective, her work often employs a mixed methods design and is interdisciplinary, drawing from gerontology and aging studies, family and community science, developmental psychology, youth development, education, anthropology, and sociology. She earned her Certified Family Life Educator (CFLE) credential to further the translation of research to applied settings.

Beyond research, Dr. Stephan is committed to advancing the development, implementation, and evaluation of evidence-based educational opportunities that support learners across the lifespan. Two primary avenues for this work include a) creating resources and fostering mentorship opportunities to ensure high-quality training exists for current and future professionals in the field of gerontology and b) promoting lifelong learning through engaging and fulfilling learning experiences for older adults.

©American Society for Engineering Education, 2026

From Body of Knowledge to Modular Implementation: A Faculty Learning Community Model for Graduate Chemical Engineering Reform

Abstract
Graduate STEM education remains largely grounded in a uniform, "one-size-fits-all" structure that prioritizes research depth over pedagogical adaptability. The Swanson School of Engineering at the University of Pittsburgh, supported by an NSF Innovations in Graduate Education (IGE) award, is addressing this gap through a personalized learning model (PLM) for graduate Chemical Engineering that includes a modularized, one-credit curriculum. This paper presents a case study of how a Faculty Learning Community (FLC) operationalized a collaboratively developed body of knowledge (BOK) into a functioning modular curriculum. In this paper, we address the following research question: How can an FLC serve as a mechanism for implementing modular, personalized graduate curricula? Specifically, what mechanisms promote faculty adoption of this educational innovation?

Throughout the 2024–2025 academic year, faculty teaching the core chemical engineering courses: Thermodynamics, Kinetics, Transport, Safety and Ethics, and Mathematical Methods met monthly to interpret the BOK, identify implementation barriers, and co-design three-level, one-credit modules aligned with foundational, graduate, and specialized learning outcomes. Guided by educational research frameworks and supported by external evaluators, the FLC employed diffusion of innovation theory and Vygotsky's scaffolding principles to iteratively refine its instructional design. Monthly meeting themes ranged from analysis and planning to process mapping, learning about just-in-time teaching, and developing "day-to-day" module blueprints for each course in the Fall 2025 pilot launch.

Early findings indicate that the FLC model effectively built community, fostered ownership, and reduced resistance to change, while highlighting structural barriers, particularly in assessment practices and inter-faculty coordination. Faculty surveys indicated high support for innovation but underscored the need for continued peer and administrative backing. The paper concludes by presenting the FLC's replicable structure, facilitation practices, and assessment tools, positioning this approach as a scalable framework for translating conceptual curriculum redesign into sustainable instructional practice.

This case study demonstrates how faculty collaboration can make graduate curriculum reform practical, flexible, and adaptable across STEM fields.

1. Introduction

Graduate engineering education remains largely organized around rigid, three-credit course structures that prioritize research depth while offering limited flexibility to address students' varied preparation, career goals, and emerging disciplinary demands. The Personalized Learning Model (PLM) addresses nationally documented concerns, including curricular inflexibility, misalignment with industry and societal needs, rising expectations, and inequities arising from the assumption of uniform student preparation. While many curricular innovations address these issues conceptually, sustained adoption is often constrained by the difficulty of translating reform into coordinated faculty practice. To address this gap, we organized a Faculty Learning Community (FLC) to implement the modular, one-credit coursework.

This work builds on two prior studies that established the PLM's conceptual and structural foundations. The first [1] introduced the PLM framework as a holistic, student-centered approach integrating instructional goals, modular task environments, scaffolding, assessment, and reflection. The second [2], reported the development of a graduate Body of Knowledge (BOK) using Group Concept Mapping with faculty and external subject matter experts. Together, these studies addressed *what* graduate curriculum reform should include. The present work focuses on *how* such reform is enacted within existing institutional constraints and live graduate classrooms.

Accordingly, this paper presents a case study of how a year-long FLC supported faculty in interpreting the BOK, identifying implementation barriers, and co-designing modular, credit-bearing graduate courses across core subject areas. The guiding research question is: ***How can an FLC serve as a mechanism for implementing modular, personalized graduate curricula?*** We examine pedagogical, organizational, and institutional factors that enabled or constrained adoption, with attention to faculty sensemaking, coordination, and sustained support during early implementation.

2. Background

2.1 An Introduction to the PLM

The PLM is a student-centered, program-level framework for modernizing STEM graduate education beyond one-size-fits-all curricula (Figure 1). The model comprises five interconnected components: Instructional Goals, Task Environment, Scaffolding of Instruction, Assessment of Performance and Learning, and Reflection and Evaluation. Grounded in personalized learning principles and Self-Determination Theory [3], the PLM aligns graduate coursework and professional development with students' evolving career aspirations.

Instructional Goals are established through Individual Development Plans (IDPs) co-developed by students and faculty. These goals are enacted within a redesigned Task Environment that replaces traditional three-credit courses with stackable, one-credit modules and complementary professional development streams (industry, academia, entrepreneurship). Instruction in this environment is intentionally scaffolded to support progression toward independence and mastery, particularly for students entering with varying levels of preparation. Ongoing assessment and structured reflection provide feedback loops that inform both student learning pathways and instructional refinement. While prior work established this conceptual model, it did not examine how the PLM is enacted through coordinated faculty practice. This issue is addressed in this study through the FLC.

2.2 The Argument for Faculty Learning Communities (FLC)

FLCs are widely recognized as an effective strategy for educational change because they embed reform within sustained, collaborative faculty practice rather than isolated interventions. Drawing on Cox's model of FLCs as communities of practice [4] and Henderson's perspectives on change in engineering education [5], FLCs address individual faculty beliefs, instructional practices, and institutional context simultaneously. As such, FLCs are well-positioned to support durable, scalable change by translating educational research into locally meaningful, collectively supported action.

Prior work in engineering education has established FLCs as an effective mechanism for bridging the research-to-practice gap in teaching [6] [7] [8], most notably through the work of Finelli et al. [9], who conceptualized the FLC as an institutional intervention grounded in change theory and communities of practice, emphasizing sustained engagement, peer accountability, reflective practice, and alignment with local context. In that work, the primary contribution of the FLC model was to move faculty beyond awareness of educational research toward intentional experimentation and change within their own courses. The present case study extends Finelli et al.'s framework by demonstrating how an FLC can operate not only as a conduit for pedagogical change but as a coordinating structure for program-level curriculum reform. Specifically, this work shows how the core elements identified by Finelli et al., that of ongoing faculty interaction, shared pedagogical language, reflective cycles, and institutional support, can be leveraged to support cross-course alignment, modular curriculum redesign, and sustained implementation through early deployment. In doing so, this study advances the FLC literature from a focus on individual instructional change to a model in which FLCs function as an enabling infrastructure for coordinated, structural transformation in engineering graduate education.

2.3 Communities of Practice and Faculty Development

Beyond diffusion and sustained adoption frameworks, this work is informed by scholarship on Communities of Practice (CoP), which conceptualizes learning as socially constructed through sustained interaction. Wenger defines a community of practice as a group engaged in shared enterprise, developing mutual engagement and a shared repertoire over time [10], [11]. In engineering education, CoPs have fostered shared pedagogy and overcome institutional constraints [12]. Recent studies demonstrate that FLCs can function as a CoP that supports curricular innovation [9], [8]. Matthew et al. provide guidance on intentionally structuring faculty CoPs to move from exploration to implementation [13], while Egwuonwu et al. emphasize the role of social capital in faculty engagement and the adoption of innovation [14]. This literature highlights the intersection of faculty development, engineering education reform, and CoP. Change occurs when faculty construct shared artifacts, negotiate policies and procedures, and develop ownership of their innovation. The present study extends prior work by examining how an FLC functioned as an enabling CoP for graduate curriculum reform.

2.4 Theoretical Framework for Diffusion and Sustained Adoption

This work is grounded in established theories of educational change and innovation adoption in STEM higher education. Rogers' Diffusion of Innovations theory frames adoption as a multi-stage process—from awareness and persuasion to implementation and sustained use—shaped by prior conditions and perceived barriers at the individual, departmental, and institutional levels [15]. Complementing this perspective, Henderson and colleagues demonstrate that durable instructional change requires coordinated strategies that address faculty beliefs, departmental norms, and institutional structures simultaneously [16]. The Designing for Sustained Adoption Assessment Instrument (DSAAI) operationalizes these insights by identifying conditions that support or inhibit adoption, including perceived complexity, compatibility with existing practices, resource availability, and interdependence among stakeholders [17], [18]. Together, this literature emphasizes that successful institutionalization and dissemination of educational innovations require intentional, multi-level approaches rather than isolated interventions [19], [20].

3. FLC Case Study

3.1 FLC Design

The FLC was situated within a large R1 engineering school and its Department of Chemical Engineering, and was designed to operationalize two PLM components: the Task Environment and Scaffolding of Instruction. Faculty redesigned existing three-credit graduate courses into three stand-alone, one-credit modules: the first, a fundamentals module, to bring all students to the same level of ChE fundamentals preparation, followed by a required graduate core module, and last, a flexible specialization module aligned with emerging topics and faculty expertise. During the initial pilot year, students continued to register for the traditional three-credit course to avoid altering institutional registration logistics. The one-credit modular structure was implemented internally within the course as proof of concept prior to the full credit reconfiguration. Traditional letter grades are used to maintain consistency with existing graduate evaluation practices. The FLC supported implementation of scaffolded instruction grounded in Vygotsky's Zone of Proximal Development [21], emphasizing progression from guided support to independent performance through assessments, projects, or exams.

Participants included faculty teaching core Chemical Engineering content (i.e., Thermodynamics, Kinetics, Transport Phenomena, Mathematical Methods, and Safety/Ethics) with two faculty per topic. The FLC was led by the PI, supported by Co-PIs from the Engineering Education Research Center, and external evaluators from Quality Evaluation Designs (QED). The group met monthly for 60–90 minutes from September 2024 through November 2025, following a structured sequence from orientation and diagnosis to design, development, and early implementation. Faculty readiness and perceptions were monitored using the QED Innovation Support Survey at multiple time points.

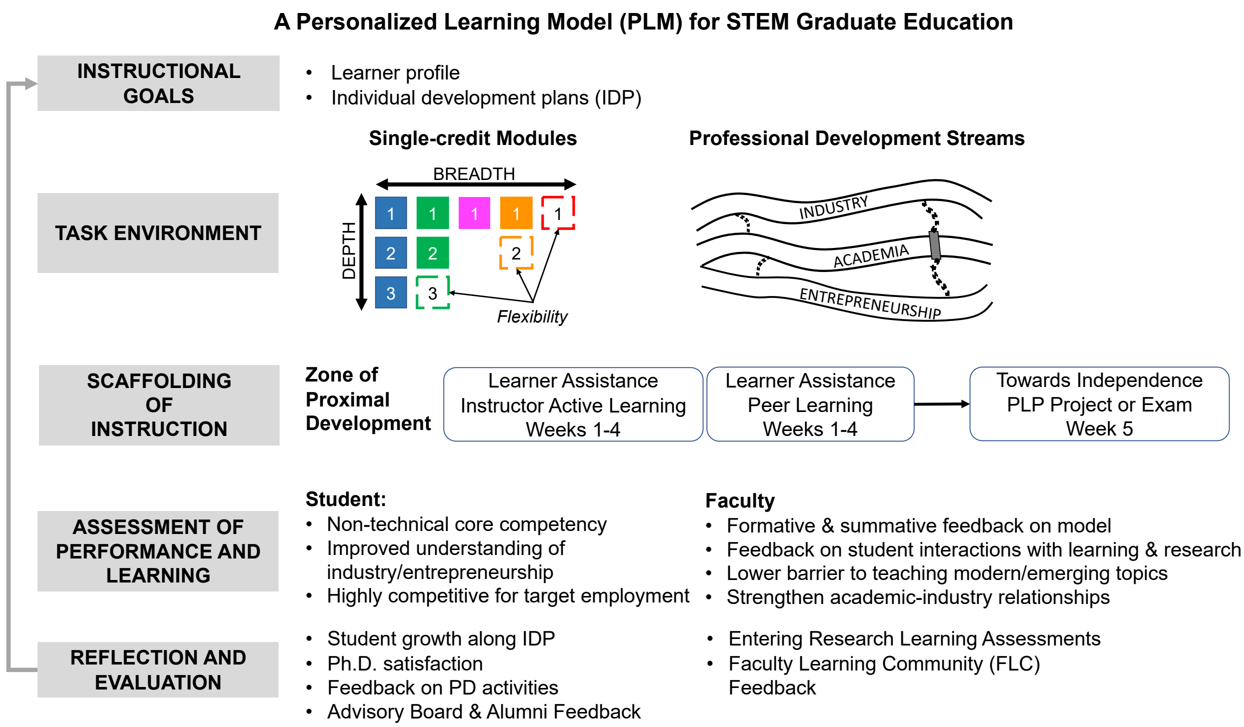

Figure 1: Overview of the Personalized Learning Model (PLM) for STEM graduate education [1]

3.2 Case Study Approach

This study employed a qualitative case study design to examine how an FLC supported the implementation of modular curriculum reform within a department. The case comprised the fourteen-month FLC supporting implementation of the PLM in graduate Chemical Engineering and was guided by the research question: *What mechanisms promote faculty adoption of this educational innovation?*

Data sources included FLC meeting materials (agendas, slides, recordings, field notes), faculty-produced artifacts (e.g., syllabi and module plans), and responses to the QED Innovation Support Survey (QISS). Survey items were analyzed descriptively to track trends in faculty perceptions over time, while open-ended responses were analyzed qualitatively to identify perceived barriers and enabling supports.

Qualitative data were analyzed using iterative thematic analysis. Codes were generated inductively from transcripts and artifacts, then refined through constant comparison across data sources to identify recurring patterns in faculty sensemaking, coordination, and adoption processes. In a second phase, themes were examined in relation to diffusion and sustained adoption frameworks to assess alignment with established change theory. The analysis aimed to generate themes within this case rather than a new formal theory. Credibility was strengthened through triangulation across data sources and an audit check of coded excerpts to ensure consistency with the themes.

3.3 Innovation Support Survey (QISS)

To evaluate how faculty perceptions changed over time and what additional support might be needed, our external evaluators, Quality Evaluation Designs (QED), created an instrument based on Rogers' diffusion of innovation [15] and the Designing for Sustained Adoption Assessment Instrument [18]. The QED Innovation Support Survey (QISS) is designed to assess faculty readiness, perceived effort, and institutional conditions associated with implementing the IGE PLM through faculty members' anonymous responses. QISS is a 5-minute, 22-item assessment of faculty support for an innovation based on the entrepreneurship principle that an innovation is most likely to be adopted when it addresses a need or solves a problem. In creating QISS, QED adapted a Sanford et al survey [22] used by designers to self-assess the value of their innovation so that the survey could be taken by those receiving an innovation. To interpret results, QED adapted Rogers' *Diffusion of Innovation* stakeholder archetypes based on their proclivity to support a particular innovation [15]: *Champion, Early Adopter, Skeptic, Resister,* and *Cave Dweller (Completely Against Virtually Everything)*. QISS yields rich information that can lead to actionable strategies by PIs and others to gauge stakeholder support, boost the odds of their innovations being adopted, or signal that the ground might not be sufficiently fertile for making the effort. QISS can identify stakeholder segments even with an extremely small sample of three to five respondents, making it a valuable tool for a small, moderate, or large department. The QISS also assesses faculty members' confidence in their ability to implement the innovation, perceived alignment with existing instructional pain points, and overall level of support for the initiative. Open-ended questions provide qualitative insight into anticipated challenges at both the individual and departmental levels, enabling formative evaluation of adoption conditions and informing strategies for sustained implementation.

4. Results and Findings

Table 1 summarizes the evolution of the FLC through four phases across a fourteen-month period, illustrating how faculty engagement progressed from initial sensemaking to sustained implementation and refinement. Early meetings (September–October 2024, Phase 1) focused on establishing shared context and surfacing faculty concerns, creating the conditions for collective problem framing rather than relying on preconceived assumptions that could lead to adopting the wrong approach. Subsequent sessions (November 2024–April 2025, Phase 2) emphasized pedagogical capacity building, evidence-informed design, and the translation of learning objectives into modular instructional plans, supported by shared tools such as pre-knowledge assessments and scaffolding strategies. At this stage, the faculty applied prior training in writing learning objectives and mapped them into modules [2]. Summer 2025 (Phase 3) marked a transition from design to action, highlighted by worked exemplars, individualized feedback, and increasing faculty ownership of redesigned courses. Finally, Fall 2025 (Phase 4) meetings documented early implementation experiences, reflective refinement, and engagement with external advisory boards, signaling a shift from local curriculum redesign to scalable, field-level contribution. Taken together, the table highlights a deliberate sequencing of activities that supported faculty mindset shifts, instructional change, and sustained curricular reform.

Table 1. FLC Timeline and Faculty Change Trajectory

Month	Focus	Summary of Activities	Major Outcomes
		Phase 1: Establish shared context and surface faculty concerns	
Sep 2024	Orientation & framing	Introduced modular curriculum concept; reviewed Body of Knowledge results; shared early exemplar of modularization; assigned barrier-reflection homework	Shared purpose and legitimacy of reform
Oct 2024	Barriers & concerns	Faculty surfaced concerns about rigor, workload, math preparation, pacing, and coordination	Barriers documented; skepticism normalized
		Phase 2: Pedagogical capacity building and evidence-informed design	
Nov 2024	Pedagogical tools	Introduced pre-knowledge surveys and scaffolding; faculty began mapping learning outcomes (LOs) into modules	Concrete strategies to address preparedness
Dec 2024	—	End-of-term pause	
Jan 2025	Evidence-informed design	Reviewed faculty support survey; integrated non-core LOs; aligned objectives with assessment	Assessment became a design constraint; innovation validated

Month	Focus	Summary of Activities	Major Outcomes
Feb 2025	Operational design	Translated LOs into day-to-day plans; One core class was used as a detailed case	Demonstrated feasibility; highlighted coordination needs
Mar 2025	Process & change mgmt.	Introduced modularization process flow; reviewed follow-up survey; discussed change strategies	Shared, replicable reform process
Apr 2025	Pedagogy & transition	Workshop on priming/JiTT; year-long synthesis; summer work planning	Pedagogical coherence; commitment to implementation
May 2025	—	End-of-term pause	
Phase 3: Turning design into action			
Jun 25	Early evidence	Faculty shared pre-test–informed adaptations; prioritized, added, and pruned content across and within courses	Data-driven instructional change
Jul 25	Worked exemplar	Full report-out of completed modular math course	Proof-of-concept; clarified expectations
Aug 25	Refinement	Individualized feedback on Module 1 designs	Quality assurance; faculty ownership
Phase 4: Shift from local curriculum redesign to scalable, field-level contribution			
Sep25	Implementation	First live delivery of modular curriculum	Transition to practice
Oct 25	Early reflection	Reported Module 1 successes/challenges, scheduled follow-ups	Iteration normalized
Nov25	Reflection & dissemination	Reflected on Modules 1–2; planned Module 3; engaged advisory boards	External validation; field contribution

Table 2 presents representative faculty quotations from the QED Innovation Support Survey across multiple time points, illustrating how perceptions, barriers, and enabling supports evolved as faculty moved from initial awareness of the PLM to early implementation and confirmation.

Table 2. Faculty Perceptions, Barriers, and Diffusion Factors Identified Through QISS Open-Ended Responses

Time Point	Adoption Stage (Rogers)	Coding Area	Representative Faculty Quotes	Interpretation
Nov 2024	Awareness	Perceptions of PLM	“I don't think I know enough about PLM innovation to make a good estimate.”	Early-stage awareness with insufficient information to form judgments; sensemaking not yet complete
	Awareness / Persuasion	Anticipated Barriers	“This will create pain points for me rather than alleviate anything.”	Initial perception of high personal cost and unclear relative advantage
	Awareness / Persuasion	Enabling Supports	“The 1-credit option will significantly lower this barrier.”	Recognition of structural advantage (lower barrier to innovation) even amid concern
Feb 2025	Persuasion	Perceptions of PLM	“This is a thoughtful improvement and should be pursued.”	Shift toward favorable attitudes as purpose and value become clearer
	Persuasion	Perceived Value	“Literally anything that can be done to create more flexibility and responsiveness in a historically rigid discipline like CHE is going to be good.”	Strong perceived relative advantage tied to flexibility and responsiveness

Time Point	Adoption Stage (Rogers)	Coding Area	Representative Faculty Quotes	Interpretation
	Decision	Implementation Challenges	“Reluctance to give up course curricula that meet a minimum perceived standard of ‘coverage.’”	Cultural norms around content coverage constrain adoption decisions
	Decision	Structural Barriers	“An open question is how to handle students who are not equipped for graduate studies.”	Need for off-ramps and alignment with student preparedness
Aug 2025	Implementation Readiness	Perceptions of PLM	“It has provided a great platform for faculty to coordinate efforts and opened opportunities for collaboration.”	FLC is identified as a key enabling support and coordination mechanism
	Implementation Readiness	Remaining Concerns	“Sometimes we try to be comprehensive… but we make things more complicated unnecessarily.”	Tension between innovation complexity and instructional coherence
	Implementation	Coordination Barriers	“Coordination of efforts (faculty, students) to move forward the proposal.”	Interdependence among faculty emerges as a dominant adoption constraint
Nov 2025	Implementation / Confirmation	Perceptions of PLM	“I think this has become a very good idea with practically no downside.”	Confirmation stage: innovation is normalized and broadly supported
	Confirmation	Sustainability Concerns	“The main challenge will likely be getting all parties on board with doing this and maintaining it for 10+ years.”	Focus shifts from feasibility to long-term sustainability
	Confirmation	Implementation Challenges	“Restructuring and modifying course content to fit into the three 1-credit modules.”	Ongoing adaptive work is required even after adoption

Tables 1 and 2 together show that faculty adoption followed a staged trajectory aligned with the FLC's structure. As the FLC progressed from orientation and diagnosis to design and implementation, faculty perceptions shifted from initial uncertainty to conditional support and, eventually, confirmation. Adoption was enabled by sustained engagement rather than a single decision point, with the FLC reducing perceived risk through sensemaking, pedagogical support, and coordination. These findings indicate that faculty adoption was driven by decreasing uncertainty and increasing instructional feasibility rather than persuasion alone.

Three primary themes emerged over the year, illuminating how faculty-engaged curriculum reform can be successfully enacted in graduate engineering education. These themes describe a shift not only in curriculum structure, but in faculty mindset, instructional practice, and collaborative norms.

<u>Faculty Adoption Increased as Uncertainty Was Reduced Through Sensemaking and Concrete Artifacts</u>**:** Faculty support for the PLM grew over time as opportunities for collective sensemaking were paired with tangible design artifacts (e.g., module outlines, process flows, worked exemplars), allowing faculty to evaluate feasibility and relevance within their own courses. Over the course of the year, faculty communicated their specific learning objectives and content, enabling them to collaborate on where it belongs and its priority within the overarching curriculum.

<u>Pedagogical Capacity Building Enabled Faculty to Implement Modular Course Structures</u>**:** Faculty adoption depended on access to specific instructional strategies, such as scaffolding aligned with the Zone

of Proximal Development, pre-tests, and JiTT [23], which supported effective teaching and shifted concerns to feasibility and execution.

Sustained Coordination Addressed Persistent Cultural and Structural Constraints During Implementation**:** As implementation progressed, challenges centered less on individual workload and more on coordination across faculty and courses, as well as tensions around content coverage. Continued FLC engagement provides a structure for managing these constraints and supporting early implementation and adoption. For example, a structural question under faculty discussion concerns progression across modules if a student does not successfully complete the foundational module. While this scenario has not historically been a problem, the modular structure requires clear policies for repetition or progression.

5. Implications for Engineering Graduate Education and Related STEM Fields

This case study shows that reform in graduate engineering education depends on mechanisms that support faculty adoption over time. Modular, one-credit curricula can be implemented when faculty are given structured opportunities for sensemaking, pedagogical capacity building, and coordination. Faculty engagement followed a staged progression from uncertainty to confirmation, consistent with diffusion-of-innovation theory.

Three implications emerge. First, FLCs can function as enabling infrastructure for graduate curriculum reform by legitimizing skepticism, clarifying expectations, and sustaining engagement through early implementation. Second, pedagogical support is essential to structural change. Faculty concerns centered on how to teach effectively within short modules rather than on modularization itself. Scaffolding, pre-knowledge assessment, and shared pedagogical language enabled faculty to maintain rigor while addressing heterogeneous preparation. Third, coordination must be addressed explicitly. As implementation progressed, challenges shifted from individual workload to cross-course alignment and scheduling, underscoring the need for sustained collective structures.

Although situated in chemical engineering, these findings highlight transferable processes for other STEM graduate programs seeking to modernize curricula while preserving disciplinary depth and faculty ownership. Revisiting our Research Question of "What mechanisms promote faculty adoption of this educational innovation (and possibly others)?", Figure 2 provides an overview of the mechanisms and processes that we engaged in over fourteen months. This conceptual model illustrates how a structured FLC functions as an enabling infrastructure for iterative curriculum reform. Through cycles of sensemaking, pedagogical capacity building, modular design, coordination, implementation, and reflection, faculty moved from initial concern to adoption of a one-credit modular curriculum. Outcomes include changes in faculty practice, curricular coherence across and within courses, and scalable processes for reforming graduate engineering education.

6. Conclusions/Future Work

This study demonstrates that a structured FLC can translate a collaboratively developed Body of Knowledge into actionable faculty practice. Over fourteen months, the FLC supported sensemaking, pedagogical capacity building, and coordination, enabling faculty to redesign traditional graduate courses into modular, one-credit offerings while maintaining rigor. With initial implementation underway, this work provides a replicable approach for bridging educational theory and institutional practice in graduate engineering education.

Future work will evaluate student learning outcomes, inter-module alignment, and longer-term faculty and administrative adoption. Ongoing assessment will incorporate classroom observation, student feedback, and longitudinal tracking to examine sustainability and scalability across programs. We compare student outcomes under the modular structure with those of prior cohorts in the traditional three-credit format. Measures include classroom observations, perceptions of the classroom environment, grade distributions across modules, and first-year Ph.D. qualifying examination performance as indicators of preparedness. These comparisons will allow examination of both immediate instructional effects and longer-term academic outcomes.

Limitations: This case is situated within a single department at a research-intensive institution, and external support structures may not be universally available. Findings primarily reflect faculty perspectives during early implementation, with student outcome data still emerging. Additional implementation cycles are needed to assess long-term impact and transferability.

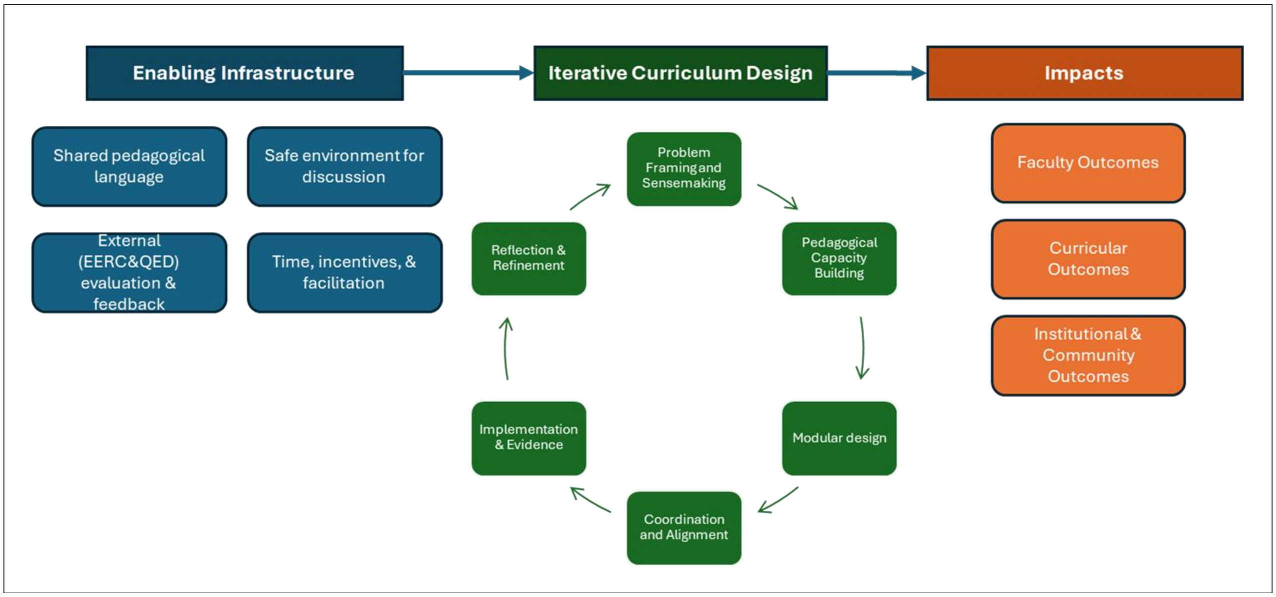

Figure 2. FLC–Driven Process for Modular Graduate Curriculum Reform.

Acknowledgments

This work is supported by a grant from the National Science Foundation (DGE-IGE 2325599). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We also thank Professors Karl Johnson, James McKone, Jason Shoemaker, John Keith, Joaquin Rodriguez, and Mohammad Masnadi for their full engagement in the FLC and in curricular reform. The authors disclose the use of ChatGPT (OpenAI) as an assistive tool for manuscript editing, organization, and clarity; no data generation, analysis, or scholarly interpretation was conducted by the tool, and all content, conclusions, and responsibility for the work rest solely with the authors.

References

[1] A. A. Dukes, V. E. Kerr, S. K. Fullerton Shirey, G. Veser, and M. E. Besterfield-Sacre, "A new personalized learning approach toward graduate STEM education: A pilot in chemical engineering," in *Proc. 2024 ASEE Annu. Conf. Exposition*, Portland, OR, USA, Jun. 2024, doi: 10.18260/1-2-46464.

[2] M. E. Besterfield-Sacre, A. A. Dukes, S. K. Fullerton, and G. Veser, "Creating a modularized graduate curriculum in chemical engineering," in *Proc. 2025 ASEE Annu. Conf. Exposition*, Montréal, QC, Canada, Jun. 2025.

[3] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being," *American Psychologist*, vol. 55, no. 1, pp. 68–78, 2000, doi: 10.1037/0003-066X.55.1.68.

[4] M. D. Cox, "Introduction to faculty learning communities," *New Directions for Teaching and Learning*, no. 97, pp. 5–23, 2004.

[5] C. Henderson and J. Froyd, “Theoretical perspectives on change in engineering education,” in *Cambridge Handbook of Engineering Education Research*, Cambridge, U.K.: Cambridge Univ. Press, 2014, pp. 57–71.

[6] R. M. Clark, M. Besterfield-Sacre, B. Parker, W. Slaughter, W. Clark, D. Budny, K. Bursic, B. Norman, and J. Patzer, “A mixed methods evaluation of flipped classroom pedagogy: An analysis across six core engineering courses,” *Advances in Engineering Education*, vol. 5, no. 3, pp. 1–39, 2016.

[7] Z. Long, S. Eddington, and J. Pauly, “Understanding the participation, perceptions, and impacts of engineering faculty learning communities: A mixed-method approach,” in *Proc. 2016 ASEE Annu. Conf. Exposition*, New Orleans, LA, USA, Jun. 2016.

[8] M. Morin, R. Goldberg, and B. Hutson, “Using faculty learning communities to create a sustainable community of practice that promotes curricular and instructional change,” in *Proc. 2023 ASEE Annu. Conf. Exposition*, Baltimore, MD, USA, Jun. 2023.

[9] C. J. Finelli, S. R. Daly, and K. M. Richardson, “Bridging the research-to-practice gap: Designing an institutional intervention using the faculty learning community model,” *Journal of Engineering Education*, vol. 103, no. 4, pp. 489–526, 2014.

[10] E. Wenger, *Communities of Practice: Learning, Meaning, and Identity*. Cambridge, U.K.: Cambridge Univ. Press, 1998.

[11] E. Wenger, R. McDermott, and W. Snyder, *Cultivating Communities of Practice: A Guide to Managing Knowledge*. Boston, MA, USA: Harvard Business School Press, 2002.

[12] L. Jonker, “Communities of practice in engineering education,” in *Proc. 33rd ASEE/IEEE Frontiers in Education Conf.*, Boulder, CO, USA, 2004.

[13] R. Matthew, et al., “A roadmap for the design and implementation of communities of practice for faculty development,” in *Proc. 2022 ASEE Annu. Conf. Exposition*, Minneapolis, MN, USA, Jun. 2022.

[14] N. Egwuonwu, et al., “Virtual communities of practice: Social capital’s influence on faculty development,” in *Proc. 2022 ASEE Annu. Conf. Exposition*, Minneapolis, MN, USA, Jun. 2022.

[15] E. M. Rogers, *Diffusion of Innovations*, 5th ed. New York, NY, USA: Free Press, 2003.

[16] C. Henderson, A. Beach, and N. Finkelstein, “Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature,” *Journal of Research in Science Teaching*, vol. 48, no. 8, pp. 952–984, 2011, doi: 10.1002/tea.20439.

[17] C. Stanford, R. Cole, J. Froyd, D. Friedrichsen, R. Khatri, and C. Henderson, “Supporting sustained adoption of education innovations: The designing for sustained adoption assessment instrument,” *International Journal of STEM Education*, vol. 3, no. 1, 2016, doi: 10.1186/s40594-016-0034-3.

[18] C. Henderson, R. Cole, J. Froyd, D. Friedrichsen, R. Khatri, and C. Stanford, *Designing Educational Innovations for Sustained Adoption: A How-To Guide for Education Developers Who Want to Increase the Impact of Their Work*. Kalamazoo, MI, USA: Increase the Impact, 2015.

[19] L. J. Shuman and M. E. Besterfield-Sacre, “Innovation through propagation: Future directions for engineering education research,” *Advances in Engineering Education*, vol. 7, no. 2, pp. 1–14, 2019.

[20] J. P. Kotter, “Leading change: Why transformation efforts fail,” in *Museum Management and Marketing*. London, U.K.: Routledge, 2007, pp. 20–29.

[21] B. Eun, “The zone of proximal development as an overarching concept: A framework for synthesizing Vygotsky’s theories,” *Educational Philosophy and Theory*, vol. 51, no. 1, pp. 18–30, 2019, doi: 10.1080/00131857.2017.1421941.

[22] C. Stanford, R. Cole, J. Froyd, D. Friedrichsen, R. Khatri, and C. Henderson, “Supporting sustained adoption of education innovations: The designing for sustained adoption assessment instrument,” *International Journal of STEM Education*, vol. 3, no. 1, p. 1, 2015.

[23] G. M. Novak, E. T. Patterson, A. D. Gavrin, and W. Christian, *Just-in-Time Teaching: Blending Active Learning with Web Technology*. Upper Saddle River, NJ, USA: Prentice Hall, 1999.