IUSE/PFE: RED A&I Curriculum Integration through Collaborative Teaching and Mentoring: Adapting an Integrated System for Engineering Formation

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1 Rationale and Context

Preparing engineers for rapidly evolving technological and societal demands requires educational models that integrate foundational theory, engineering practice, and professional identity formation. The National Academy of Engineering's *Educating the Engineer of 2020* report highlights the need for early design exposure and multidisciplinary learning to develop essential competencies for modern engineers [1]. Research from the NSF Engineering Education Coalitions Program shows that early, relevant engineering experiences improve persistence and graduation rates [2].

Despite a strong history of educational innovation, including the studio classroom [3, 4] and the Inventors Studio program [5, 6], the Department of Mechanical, Aerospace, and Nuclear Engineering (MANE) at Rensselaer Polytechnic Institute (RPI) identified three persistent challenges: (1) difficulty integrating foundational principles with upper-level engineering content, (2) limited multi-semester design engagement, and (3) inconsistent early exposure to industry and engineering career pathways. These challenges mirror findings that siloed curricula inhibit knowledge transfer and innovation [1, 4].

To address these needs, the MANE Department developed a multipronged strategy built around four pillars: disciplinary integration, longitudinal project engagement, structured industry engagement, and faculty development focused on pedagogy.

1. Disciplinary Integration through Knowledge Integration (KI) Activities [7]: KI activities embed cross course conceptual linking within sophomore and junior level courses. These activities intentionally require students to apply foundational principles (e.g., conservation of mass, momentum, and energy) to realistic engineering problems that draw on multiple domains. This supports engineering reasoning early in the curriculum and multidisciplinary learning.
2. Longitudinal Projects through the Vertically Integrated Projects (VIP) Model [8]: MANE implemented a course embedded VIP structure. Students encounter components of a shared engineering challenge across multiple required courses, enabling progressive mastery of technical and systems level concepts. Embedding the VIP within existing courses expands access, eliminates extracurricular barriers, and supports cumulative learning.
3. Structured Industry Engagement via Engineer in Residence (EIR) [9]: To strengthen students' professional identity formation, the department launched an EIR program in which department alumni engage students on a monthly basis through office hours, guest lectures, panel discussions, and small group mentorship. This model enhances earlier departmental programs (e.g., Industry Day) by establishing regular, relational, and career focused engagement.
4. Faculty Development: A core component of the project's culture change strategy is strengthening faculty capacity for collaborative, research informed teaching.

This work is an adaptation and extension of the NSF IUSE/PFE RED model from Colorado State University's ECE Department [7, 10], integrating engineering education research, organizational change theory, and faculty development strategies. Essential to this effort is sustainable scale up to a large department and implementation across four degree programs. Knowledge Integration serves as a cross cutting mechanism to support both pedagogical and cultural transformation. This paper discusses implementation progress to date at a high-level, with details for each pillar presented in other papers under review for this same conference.

2 Knowledge Integration: Methods and Results

2.1 Methods

Two KI activities were implemented. The first spanned MANE 4070 Aerodynamics and MANE 4060 Aerospace Structures, taken concurrently by many students. Early coverage of aerodynamic fundamentals enabled both instructors to highlight how aerodynamic loads inform structural design. Both courses used XFOIL for aerodynamic load prediction. Aerospace structures students then applied these loads using finite element analysis (FEA) to evaluate stresses, strains, and potential failure. Eight KI homework problems were embedded in Aerospace Structures throughout the semester, increasing in complexity and synchronized with the Aerodynamics course. For students not concurrently enrolled in Aerodynamics, additional notes and tutorials were supplied and peer-supported learning opportunities were implemented through a certificate-based assessment option. A second KI activity was implemented in MANE 4500 Modeling and Control of Dynamic Systems. An in-class assignment required students to integrate thermodynamics and heat transfer concepts to derive an ODE describing a thermal system and then make open-ended design decisions to meet specified requirements.

Pre- and post-assignment "wrapper" surveys measured prior knowledge, challenge level, resources used, and perceived value of the assignments through both closed- and open-response questions. Questions prior to an assignment asked students about their confidence applying the concepts needed to complete the assignment successfully. Students might also be asked to explain the approach they planned to take to complete the assignment. A post-wrapper survey asked students about their perceived difficulty, were they successful, what other support they might need to complete it successfully. Having student responses to wrappers in conjunction with the actual results of the assignments provides a more complete picture of student learning, allowing for real time instructional adjustments [11, 12].

2.2 Results

Students in Aerospace Structures demonstrated improved ability to connect theory across courses. Homework evidence showed meaningful integration of aerodynamic loads with structural analysis, and students reported that shared use of XFOIL and FEA clarified real-world engineering workflows. Students not concurrently enrolled in Aerodynamics initially struggled, but shared notes and peer support increased accessibility. Surveys indicated that students valued seeing explicit course interconnections. This successful case study was well-received by department faculty.

In Modeling and Control of Dynamic Systems, many students appreciated the realistic, multidisciplinary nature of the assignment and recognized how prior coursework informed system modeling. Students recently taking Thermodynamics or Heat Transfer found the task manageable, while others struggled due to limited prerequisite exposure. Some students felt overwhelmed by open-endedness, yet many noted that tackling complex, realistic problems strengthened their engineering mindset. The activity demonstrated feasibility for transfer between instructors, and department faculty expressed interest in additional short KI activities across the curriculum.

3 Vertically Integrated Projects: Methods and Results

3.1 Methods

Faculty introduced an embedded VIP centered on energy harvesting Luminescent Solar Concentrators (LSCs), which use luminescent materials to absorb sunlight and reemit at longer wavelengths, directing light to photovoltaic (PV) cells via total internal reflection. Three coordinated assignments engaged students at different curricular stages:

1. ENGR 1600 Materials Science (first year): explored PV efficiency as a function of wavelength through lecture material and a brief concept check,
2. MANE 2110 Numerical Methods and Programming for Engineers (second year): Monte Carlo raytracing simulations of light propagation, reflection, scattering, and absorption in a 2D LSC, and
3. MANE 4730 Heat Transfer (third year): heatsink design to maintain PV temperature below 35°C under concentrated solar flux.

In addition to student work, "wrapper" surveys assessed students' perceptions, and assignment artifacts were analyzed for systems-level reasoning in which they integrated knowledge across multiple domains [13, 14].

3.2 Results

Across courses, students demonstrated increasing conceptual sophistication. In Materials Science, students recognized factors limiting PV efficiency, though some misconceptions indicated a need for improved scaffolding. Numerical Methods and Programming students successfully generated simulation results and demonstrated understanding of how optical interactions and geometry shape LSC performance. Heat Transfer students articulated clear thermal–optical tradeoffs and recognized how increasing concentration improves photon capture but increases thermal load. Many referenced earlier VIP assignments, demonstrating longitudinal knowledge transfer. Students valued the real-world relevance of the assignments. Challenges included limited hands-on experience and depth in Materials Science and time-intensive documentation requirements in Heat Transfer.

4 Student Professional Formation: Methods and Results

4.1 Methods

The project has piloted three EIR activities: (1) Monthly Office Hours with an IBM engineer and alumnus, (2) Industry Hour for First-Year Students, featuring two Naval Nuclear Laboratory engineers, and (3) Guest Lecture in MANE 2720 Fluid Mechanics on industrial glass forming processes, delivered by an engineer from Corning, Inc. Promotional activities were expanded after initial low attendance in the Monthly Office Hours, including a meet-and-greet scheduled immediately after large lecture courses overlapping with EIR visits.

4.2 Results

Office hour attendance has been modest, but students appreciate informal, low-stakes opportunities for career advice. The meet-and-greet drew approximately 25 students with high engagement; post-event surveys reflected unanimous satisfaction and strong interest in future events. The Industry Hour successfully supported undecided first-year students in early major exploration. In the Fluid Mechanics guest lecture, 113 of 136 respondents rated the session as "Helpful" or "Very Helpful," with $> 85\%$ of comments positive and many requests for additional industry-focused content. EIR is a work in progress, and the team continues to respond to suggestions from students as to how to increase engagement with and interest in this important opportunity.

5 Faculty Teaching Development: Methods and Results

5.1 Methods

In Fall 2024, a virtual workshop titled "Leveraging Cognitive Science to Teach Engineering Innovation" was offered. Faculty were assigned short readings using a jigsaw structure to promote distributed expertise across participants. Although attendance was modest (six participants), the session successfully initiated engagement with faculty beyond the grant PIs and introduced research literature that informed the project's pedagogical strategies. In Spring 2025, a more comprehensive three session "Helping Students Learn" series was delivered as an in person/hybrid Lunch and Learn format to increase accessibility. Sessions addressed: (1) accessing students' prior knowledge, (2) supporting practice and knowledge transfer, and (3) designing meaningful assessments. MANE faculty received priority registration, with institute wide participation allowed afterward. A certificate option required attending all sessions and completing course specific implementation assignments. Four faculty earned the certificate, though none were from MANE. To extend ongoing professional development, the project team established a recurring "RED Thread" segment in monthly MANE department meetings. Each 20 minute session featured examples of RED activities, pedagogical guidance, and faculty discussion, focusing on topics such as prior knowledge activation and knowledge integration. Additionally, a curated collection of engineering education books referenced in workshops was made available for faculty borrowing.

5.2 *Results*

Participation increased substantially from fall to spring, with 17–18 attendees in the first two Lunch-and-Learn sessions. Feedback indicated that faculty gained actionable teaching strategies and valued the hybrid format. RED Thread discussions sustained momentum, with faculty expressing interest in future topics and engaging in discussion about integrative teaching challenges. The availability of books further broadened access to pedagogical resources. Collectively, these efforts supported shared pedagogical language, greater instructional alignment and faculty engagement, and laid groundwork for sustained cultural change toward collaborative, research informed instruction.

6 Conclusion

To date, the initiative is advancing an integrated, evidence-based framework supporting professional formation of engineers in MANE at RPI. KI activities are strengthening cross-course conceptual integration, the embedded VIP is providing progressive systems-level experiences, the EIR program is enhancing professional identity formation, and faculty development reinforces research-informed teaching practices. Together, these components provide a scalable pathway for sustained departmental transformation aligned with national engineering education reform goals and those of MANE at RPI to ensure our graduates are equipped and empowered to address the big needs of our world.

While these results are encouraging, the program continues to work through several challenges. Difficulties persist in overcoming the siloed teaching paradigm due to faculty's limited time availability. We continue to combine top-down (e.g. recurring department meeting sessions), and bottom-up (e.g. specific activities that stimulate collaboration) approaches to grow a more collaborative teaching culture. Particular to this program, it remains challenging to effectively integrate curriculum in a large multi-program department in which the timing of when students take classes varies greatly. Approaches such as structured peer support and modular activity design are helping and ongoing iterations will continue to focus on the scalability and sustainability goals.

New opportunities have emerged from the activities supported by this program. We have identified potential alignment of our Engineers in Residence with a recent restructuring of career support and experiential learning at RPI. A specific goal would be to support students who struggle to obtain an internship by third year, helping them to craft an individual professional development plan. Faculty professional development activities have revealed a broader community of faculty beyond our department eager to apply evidence-based pedagogy. We are exploring a potential partnership with a nearby community college that supplies a pipeline of transfer students, with an emphasis on progressive knowledge transfer and earlier exposure to multidisciplinary engineering reasoning.

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References

[1] National Academy of Engineering, “5 Recommendations,” in *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington, DC: National Academies Press, 2005, pp. 51–58. [Online]. Available: https://www.nationalacademies.org/publications/11338

[2] H. R. Coward, C. P. Ailes, and R. Bardon, “Progress of the engineering education coalitions, final report,” SRI International, prepared for Engineering Education and Centers Division, National Science Foundation, Arlington, VA, Tech. Rep., 2005, p. 22.

[3] R. Lahey and G. Gabriele, “Curriculum reform at Rensselaer,” in *Technology-Based Re-Engineering Engineering Education Proceedings of Frontiers in Education FIE’96 26th Annual Conference*, vol. 2, 1996, pp. 663–666.

[4] J. Schumacher and G. Gabriele, “Product design and innovation: a new curriculum combining the humanities and engineering,” in *FIE’99 Frontiers in Education. 29th Annual Frontiers in Education Conference. Designing the Future of Science and Engineering Education. Conference Proceedings*, vol. 1, 1999, pp. 11A6/19–11A6/24.

[5] B. L. Swersey and W. Foley, “Teaching innovation and entrepreneurship through design in inventor’s studio,” in *ASEE Annual Conference Proceedings*, Nashville, TN, 2003, pp. 5503 – 5508.

[6] The Lemelson Foundation, “The Burt Swersey Inventor’s Studio established at Rensselaer Polytechnic Institute,” https://www.lemelson.org/the-burt-swersey-inventors-studio-established-at-rensselaer-polytechnic-institute/, accessed: 2026-01-19.

[7] A. A. Maciejewski, T. W. Chen, Z. S. Byrne, M. A. De Miranda, L. B. S. McMeeking, B. M. Notaros, A. Pezeshki, S. Roy, A. M. Leland, M. D. Reese, A. H. Rosales, T. J. Siller, R. F. Toftness, and O. Notaros, “A holistic approach to transforming undergraduate electrical engineering education,” *IEEE Access*, vol. 5, pp. 8148 – 8161, 2017. [Online]. Available: http://dx.doi.org/10.1109/ACCESS.2017.2690221

[8] M. Baxter, B. Byun, E. J. Coyle, T. Dang, T. Dwyer, I. Kim, C.-H. Lee, R. Llewallyn, and N. Sephus, “On project-based learning through the vertically-integrated projects program,” in *Proceedings - Frontiers in Education Conference, FIE*, Rapid City, SD, 2011, p. T1F (7 pp.). [Online]. Available: http://dx.doi.org/10.1109/FIE.2011.6143064

[9] M. Friesen, N. Ibrahim, G. McSorley, and S. Mattucci, “Engineers-in-residence programs as a framework for industry engagement in undergraduate engineering education: Challenges and opportunities,” *Proceedings of the Canadian Engineering Education Association (CEEA)*, Oct. 2019. [Online]. Available: https://ojs.library.queensu.ca/index.php/PCEEA/article/view/13701

[10] A. A. Maciejewski, T. Chen, Z. S. Byrne, M. D. Reese, B. M. Notaros, A. Pezeshki, S. Roy, A. M. Leland, L. B. S. McMeeking, and T. J. Siller, “Throwing away the course-centric

teaching model to enable change," in *ASEE Annual Conference and Exposition, Conference Proceedings*, Salt Lake City, UT, 2018.

[11] A. Ratnayake, A. Bansal, N. Wong, T. Saseetharan, S. Prompiengchai, A. Jenne, J. Thiagavel, and A. Ashok, "All 'wrapped' up in reflection: supporting metacognitive awareness to promote students' self-regulated learning," *Journal of Microbiology and Biology Education*, vol. 25, no. 1, pp. e00 103–23, 2024. [Online]. Available: https://journals.asm.org/doi/abs/10.1128/jmbe.00103-23

[12] L. B. Nilsen, *Creating Self-Regulated Learners: Strategies to Strengthen Students' Self-Awareness and Learning Skills*. New York, NY: Routledge, 2013.

[13] T. L. Spalding and G. L. Murphy, "Effects of background knowledge on category construction," *Journal of Experimental Psychology: Learning, Memory, and Cognition*, vol. 22, no. 2, p. 525–538, 1996. [Online]. Available: https://doi.org/10.1037/0278-7393.22.2.525

[14] S. A. Ambrose, M. W. Bridges, M. DiPietro, M. C. Lovett, and M. K. Norman, *How Learning Works: Eight Research-Based Principles for Smart Teaching*, 2nd ed. San Francisco, CA: John Wiley and Sons, 2023.