Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #48449

Transforming Undergraduate Education to Educate the Whole Engineer: Implementing 100% Experiential Learning at Wake Forest Engineering Through Grounding to Learning Theories, Motivation Theories, Strategic Change Management, and Character

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ABSTRACT

This paper presents a comprehensive framework for transforming undergraduate engineering education through the successful implementation of a 100% experiential learning curriculum at Wake Forest Engineering. While extensive research demonstrates the effectiveness of experiential learning in engineering education, curriculum-wide implementations remain rare, with most programs restricting experiential approaches to isolated courses. To address this gap, Wake Forest Engineering (established in 2017) designed and implemented a fully experiential curriculum to realize its distinctive mission of "Educating the Whole Engineer for Human Flourishing." The implementation framework integrates multiple learning theories (Kolb's Experiential Learning, Situated Learning, Constructivism, Cognitive Apprenticeship) with complementary motivational theories (Achievement Goal Theory, Self-Determination, Flow, Expectancy-Value) to inform curriculum design and pedagogical practices. Using Kotter's Eight-Step Change Model and guided by leader character dimensions, the department successfully orchestrated organizational transformation while building faculty capacity.

Outcomes of the integrated experiential learning model demonstrate significant success: faculty development, student preparation (95% job placement, high student retention, professional identity development, student diversity (40% women, 25% racial/ethnic diversity), and measurable character development. This comprehensive approach propelled Wake Forest Engineering to become the highest-ranked academic program on campus (14th out of 270 institutions in 2023 US News Best Undergraduate Engineering Programs). This case study of curricular transformation provides evidence-based strategies and practical insights for institutions seeking to implement experiential learning across engineering curricula, ultimately transforming how we prepare engineers to address complex societal challenges through holistic education.

Keywords: experiential learning, engineering education, curriculum development, change management, student-centered pedagogies, whole engineer education, learning theories, motivational theories

I. INTRODUCTION AND THEORETICAL FOUNDATIONS

Experiential learning has emerged as a transformative force in higher education, fundamentally changing how students engage with knowledge. While often simply defined as "learning by doing," experiential learning encompasses a rich variety of approaches including project-based work, community engagement, design challenges, laboratory investigations, and problem-based learning. What distinguishes these educational experiences is their open-ended, authentic nature—they provide structured scaffolding but lack predetermined solutions or pathways, mirroring the complexity students will encounter in professional practice.

The impact of experiential learning in engineering education is particularly significant, as it bridges the persistent gap between theory and practice. Research demonstrates that experiential approaches enhance deep learning, practical competence, and civic engagement (Coker & Porter, 2015), with meta-analyses revealing that experiential learning pedagogies consistently outperform traditional methods (Burch et al., 2016). Beyond academic achievement, experiential learning strengthens professional development, career preparation, communication skills, team effectiveness, professional identity formation, and character development.

Despite these documented benefits, widespread implementation across entire engineering curricula remains rare. Most engineering programs continue to rely predominantly on lecture-based approaches, with experiential components typically limited to isolated courses such as capstone design or selected laboratories. This represents a significant missed opportunity for engineering education, especially considering the evolving demands of the engineering profession.

This paper contributes to our understanding of experiential learning implementation by presenting the development of Wake Forest Engineering—a program built from its founding on the principle of 100% experiential learning across the curriculum. We document how this commitment to "Educate the Whole Engineer for Human Flourishing" was realized through intentional curriculum design, faculty development, and organizational change strategies.

Theoretical Foundations: Learning Theories Supporting Experiential Learning

A critical gap identified in engineering education is the limited theoretical grounding of experiential learning implementations. A recent systematic literature review of experiential learning in engineering education from 1995-2020 revealed that only 25% of studies explicitly framed their work within established theoretical frameworks (Tembrevilla, Phillion & Zeadin, 2024). This theoretical disconnect limits the effectiveness of experiential learning implementation and hinders the development of evidence-based practices.

Several learning theories provide robust foundations for experiential learning in engineering education:

Kolb's Experiential Learning Theory (KELT) has been widely applied in higher education, particularly in engineering. Kolb's Experiential Learning Theory being particularly influential (Healey & Jenkins, 2000; Kolb & Kolb, 2005, 2022) for its emphasis of a cyclical learning process that recognizes individual learning styles (Kolb & Kolb, 2005). The theory structures learning through a cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Healey & Jenkins, 2000). In engineering education, this approach enhances understanding of complex concepts and promotes active learning (Widiastuti & Budiyanto, 2018; Abdulwahed & Nagy, 2009). It has been successfully implemented in various contexts, including laboratory education (Abdulwahed & Nagy, 2009), design competitions (Gadola & Chindamo, 2019), and construction engineering courses (Lee et al., 2008). The theory accommodates diverse learning styles and helps develop soft skills crucial for professional success (Haritha & Rao, 2024). Mathematical modeling of Kolb's cycle has revealed its robustness in accommodating students' varying learning abilities (Abdulwahed et al., 2008). Recent studies using ethnography have identified key themes in experiential learning for engineering students, including cooperative learning, consistency, relevance, simulation, and transparency (Mehta & Mehta, 2023).

Situated Learning Theory (SLT) supports experiential learning in higher education and engineering by emphasizing contextual, authentic environments for skill development (Castillo & Harris, 2024; Gómez et al., 2015). This approach enhances students' ability to address complex problems and engage with communities (Castillo & Harris, 2024). Experiential learning in engineering education has evolved since the 1950s, with recent focus on first-year students (Tembrevilla & Phillion, n.d.). Key elements for successful implementation include stakeholder collaboration, student engagement, scaffolding, assessment, reflection, faculty support, and technology integration (Tembrevilla, Phillion & Zeadin, 2024). Studies have shown positive outcomes in student satisfaction, academic achievement, and reinforced learning experiences (Tembrevilla, Phillion & Zeadin, 2024; Ghrayeb & Vohra, 2011). However, most research focuses on single-course implementations, suggesting a need for broader studies to understand the full impact of experiential learning in engineering education (Jamison et al., 2022).

Transformative Learning Theory (TLT) supports experiential learning in higher education and engineering by enhancing students' critical thinking, self-reflection, and worldview transformation (Douglas Tong Kum Tien et al., 2019). TLT combined with cognitive and experiential learning theories can develop technical skills and societal commitment in engineering students (Daramola, 2018). Implementing TLT in engineering education involves questioning assumptions, facilitating conceptual transformation, and integrating information technologies (Chen, 2007). Experiential learning, a key component of TLT, provides practical opportunities for students to apply theoretical knowledge (Ghrayeb & Vohra, 2011; Lee et al., 2008). Successful implementation of experiential learning in engineering education requires collaboration with stakeholders, student engagement, scaffolding, assessment, reflection, faculty support, and technology integration (Tembrevilla, Phillion & Zeadin, 2024). However, large class sizes can hinder the effectiveness of transformative learning in engineering education (Daramola, 2018). Overall, TLT and experiential learning enhance engineering education by promoting holistic skill development and preparing students for complex global challenges.

Social Cognitive Learning Theory (SCLT) supports experiential learning by emphasizing the role of social context in learning (Purzer, 2009). Key elements for successful implementation include relevance, student engagement, scaffolding, assessment, reflection, faculty support, and technology integration (Tembrevilla, Phillion & Zeadin, 2024). Studies have shown that experiential learning positively impacts cognitive outcomes in technology and engineering teacher preparation (Ernst, 2013) and enhances students' performance in construction engineering education (Lee et al., 2008). Furthermore, contextual supports and barriers influence choice behavior in engineering majors through self-efficacy (Lent et al., 2003).

Piaget's Constructivist Learning Theory (PCLT) supports experiential learning in higher education and engineering by emphasizing active student involvement and knowledge construction (Genalo et al., 2004). This approach aligns with the hands-on nature of engineering education, particularly in laboratories and project-based courses. Constructivism promotes student-centered learning environments where learners connect new ideas to existing knowledge (Kant et al., 2011). In engineering education, this theory has been applied through problem-based learning, projects, and group discussions (Erawati & Adnyana, 2024). Experiential learning opportunities have been successfully implemented in various engineering programs, enhancing students' practical skills and understanding (Ghrayeb & Vohra, 2011). The constructivist approach is particularly effective in developing professional competence and preparing students for industry. Successful implementation of experiential learning in engineering education involves collaboration with stakeholders, student engagement, and faculty support. Utilizing differentiation frameworks and Piagetian theories can further enhance the effectiveness of experiential learning activities in engineering education (Brenda Hutton-Prager, 2018).

Vygotsky's Social Constructionist Learning Theory supports experiential learning in higher education and engineering by emphasizing the importance of social interaction and scaffolding in knowledge construction. This approach has been applied to problem-based learning in nursing education (Chen et al., 2009) and engineering design courses (Cheville, 2010). Experiential learning, rooted in constructivist theories, has been shown to improve cognitive outcomes and enhance students' abilities in electronic design (Cheville, 2010). The integration of Vygotsky's zone of proximal development concept has been used to identify students' learning progress in engineering design courses (Autrey et al., 2018). Overall, these studies demonstrate the effectiveness of social constructionist and experiential learning approaches in engineering education.

Cognitive Apprenticeship Theory (CAT) supports experiential learning in higher education and engineering by making expert problem-solving strategies visible to novices (Poitras & Poitras, 2011). Cognitive apprenticeship theory, developed by Collins, Brown, and Holum (1991), provides a robust framework for understanding how experiential learning can be structured to support the development of expert thinking and practice. This theory extends traditional apprenticeship methods to cognitive skills by making expert thinking processes visible and accessible to learners through methods such as modeling, coaching, and scaffolding (Collins & Kapur, 2006). Research has demonstrated that cognitive apprenticeship aligns closely with experiential learning principles by emphasizing authentic context, situated learning, and the gradual transfer of responsibility from expert to novice (Dennen & Burner, 2009). This approach embeds learning in authentic activities and social contexts, enhancing students' ability to solve real-world problems (Poitras & Poitras, 2013). Studies have shown that cognitive apprenticeship is favored by engineering students regardless of learning style preferences (Poitras & Poitras, 2011) and can increase self-efficacy and interest in small business careers (Varghese et al., 2012). Implementation of experiential learning in engineering education requires relevance, student engagement, scaffolding, assessment, reflection, faculty support, and technology integration (Tembrevilla, Phillion & Zeadin, 2024). Computer-based learning environments designed using cognitive apprenticeship principles can further support engineering students' skill development outside the classroom (Poitras & Poitras, 2013). Overall, these approaches provide a significantly better learning environment for engineering subjects compared to traditional teaching methods (Lee et al., 2008).

These learning theories point to six common elements that have pedagogical implications that will be detailed later: (1) *Active Construction of Knowledge*: most theories emphasize that learners actively construct meaning rather than passively receive information. (2) *Context Importance*: most theories (Situated Learning, Communities of Practice, Authentic Learning, Ecological Systems) emphasize the importance of authentic contexts. (3) *Reflection Component*: many theories highlight reflection as crucial to transforming experience into learning. (4) *Social Dimension*: most theories emphasize the social nature of learning. (5) *Application Focus*: these theories value the application of knowledge in authentic situations where there is not one correct solution. (6) *Agency Emphasis*: many of these theories emphasize learner agency to promote student ownership of the learning while providing appropriate scaffolding.

Motivational Theories Supporting Experiential Learning

Beyond learning theories, motivational theories provide additional theoretical grounding for understanding why experiential learning approaches are particularly effective in engineering education. Engineering educators have often not integrated learning theories and motivational theories together to study and implement effective pedagogies, but this integration is essential to experiential learning.

Self-Determination Theory (SDT) explains why experiential learning is inherently motivating - it satisfies our basic psychological needs for autonomy (through choice in projects), competence (through hands-on mastery), and relatedness (through collaboration) [Ryan and Deci, 2000]. As Ryan and Deci note, these conditions foster intrinsic motivation, which leads to deeper engagement and more persistent learning efforts. SDT reminds us that humans have an inherent need for autonomy - the sense that one's actions are self-determined rather than controlled by external forces. Experiential learning approaches typically provide students with greater choice in determining their learning pathways, project topics, and problem-solving strategies. This autonomy support is consistently linked to increased intrinsic motivation, deeper engagement, and more persistent learning efforts.

Csikszentmihalyi's Flow Theory (CFT) explains the unique engagement we see in experiential learning activities [Csikszentmihalyi, 1990]. When experiential activities provide the right balance of challenge and skill, learners can enter a state of complete absorption and intrinsic reward. This explains why students often lose track of time during immersive experiential projects - they're experiencing flow states that traditional passive learning rarely induces. CFT illuminates why well-designed experiential learning activities can be so engaging. Flow occurs when learners face challenges that are optimally matched to their current skill level - neither too easy (leading to boredom) nor too difficult (causing anxiety). Experiential learning, when properly scaffolded, creates conditions for flow experiences by providing clear goals, immediate feedback, and appropriately challenging tasks. These flow states are characterized by deep concentration, loss of self-consciousness, and intrinsic reward.

Expectancy Value Theory (EVT) directly address the value component of experiential learning's authentic contexts [Wigfield and Eccles, 2000]. By connecting learning to real-world applications and personal interests, experiential approaches increase all forms of subjective value - utility value (usefulness), attainment value (personal importance), and intrinsic value (enjoyment). This heightened perceived value motivates greater effort and persistence. EVT also explains why the authentic contexts of experiential learning enhance motivation. When students perceive high value in a learning activity—whether utility value (usefulness for future goals), attainment value (personal importance), or intrinsic value (enjoyment)—they are more likely to engage deeply. Experiential learning typically increases all three value components by connecting learning to real-world applications, personal interests, and enjoyable hands-on activities.

Bandura's Social Cognitive Theory (SGT) highlights how experiential learning builds self-efficacy—a person's belief in their ability to succeed in specific situations [Bandura, 2001]. Through mastery experiences (successful task completion), vicarious experiences (observing others succeed), verbal persuasion (encouragement), and managing physiological states (reducing anxiety), experiential learning provides all four sources of self-efficacy development. Experiential learning builds self-efficacy through what Bandura called "mastery experiences" - successful completion of challenging tasks. Each successful experience in an authentic context strengthens a learner's belief in their capabilities, creating a positive cycle of increased confidence leading to greater willingness to tackle new challenges.

Achievement Goal Theory (AGT) distinguishes between mastery goals (focused on learning and improvement) and performance goals (focused on demonstrating ability relative to others). Experiential learning environments typically promote mastery goal orientations by emphasizing process over product, effort over innate ability, and personal growth over competition. Elliott and Dweck's (1988) research shows that mastery goal orientations lead to greater persistence in the face of challenges, deeper learning strategies, and more positive attitudes toward learning. The process-oriented nature of experiential learning aligns perfectly with AGT by promoting mastery goals (focusing on learning and improvement) rather than performance goals (demonstrating ability relative to others). This mastery orientation leads to greater resilience when facing obstacles and deeper approaches to learning. These motivational mechanisms work synergistically in experiential learning settings, creating conditions where students are not just cognitively engaged but emotionally and behaviorally invested in the learning process.

Interest Development Theory (IDT) via a four-phase model explains how experiential learning supports the transformation of situational interest (triggered by environmental features) into well-developed individual interest (a relatively enduring predisposition) [Renninger et al., 2014]. The novelty, personal relevance, hands-on engagement, and social interaction typical of experiential learning initially trigger situational interest. Through sustained engagement with meaningful content, this situational interest can develop into more enduring individual interest, characterized by stored knowledge, value, and positive affect. This development is critical for long-term motivation and continued engagement with content.

Weiner's Attribution Theory (AT) addresses how students interpret the causes of their successes and failures [Weiner, 1985]. Experiential learning provides clear connections between effort, strategy, and outcomes, helping students develop adaptive attributional patterns—seeing success as due to controllable factors (effort, strategy) rather than fixed abilities or luck.

The integration of these motivational theories shows that experiential learning is not merely effective for cognitive development but also creates optimal conditions for motivation and engagement. By satisfying basic psychological needs, providing optimal challenge, connecting learning to authentic contexts, building self-efficacy, promoting mastery goals, developing interest, and supporting adaptive attributions, experiential learning approaches address multiple dimensions of student motivation simultaneously. This multifaceted motivational support helps explain why experiential learning often leads to deeper engagement, greater persistence, and more meaningful learning outcomes than traditional instructional approaches.

Research Gap and Paper Contribution

Despite the extensive theoretical support for experiential learning and evidence of its effectiveness, comprehensive implementations across entire engineering curricula remain uncommon. Most research focuses on single-course implementations, with curriculum-wide frameworks representing only 7% of published studies (Tembrevilla, Phillion & Zeadin, 2024). This gap represents a significant opportunity for advancing engineering education. This paper contributes to addressing this gap by presenting the development and implementation of a comprehensive experiential learning curriculum at Wake Forest Engineering. In the following sections, we describe:

1. The institutional context and founding vision of Wake Forest Engineering
2. The structure and integration of experiential learning across the engineering curriculum
3. Change management strategies that enabled 100% experiential learning implementation
4. Key insights and recommendations for other institutions

Through this case study, we demonstrate how intentional program design grounded in learning theory can transform engineering education and prepare graduates who possess both technical competence and professional capabilities.

II. WAKE FOREST ENGINEERING PROGRAM CONTEXT

The Board of Trustees of Wake Forest University (Winston Salem, North Carolina) approved the new Department of Engineering in 2016 with support from the then President (Nathan Hatch) and then Provost (Rogan Kersh). Wake Forest Engineering was launched in 2017 with the appointment of the author (Pierrakos) as the Founding Chair in January 2017, the founding team arriving in July 2017, and the inaugural cohort of students arriving six weeks later in August 2017. Despite admissions projecting only 26 students (15% women) for the inaugural class, 55 students enrolled—more than double the expected number. The founding team faced the remarkable challenge of developing a comprehensive engineering program from scratch. At the time the founding team arrived on campus (July 2017), there was no website, curriculum, vision, operating budget, equipment, or furniture. We needed to build the airplane as we were flying it. This launch and innovative aspects of reimagining and rethinking engineering education at Wake Forest University are detailed in previous publications (Pierrakos, 2024; Pierrakos, 2025; Pierrakos and Kenny, 2025). In this paper, the focus is on Wake Forest Engineering's intentionally to leverage student-centered, project-based learning, and experiential learning throughout all four years of the curriculum in order to support the vision of the Wake Forest Engineer, a modern engineer.

Vision and Values

Pierrakos established a clear vision to "Educate the Whole Engineer for Human Flourishing" through an interdisciplinary, integrated, and student-centered curriculum. Together, the founding team established six shared values (empowerment, integrity, inclusion, compassion, growth, and joy) to shape the culture, program development, curriculum design, faculty hiring, pedagogical strategies, advising, space renovations, student recruitment, etc. The founding team deliberately created an inclusive environment from the start. While the admissions team predicted only 15% women in the inaugural class, the program achieved 40% female enrollment, a percentage they maintained in subsequent years. By year three, Wake Forest Engineering had grown to nearly 200 students, becoming the fourth largest and one of the most diverse among the 30 departments in the College of Arts and Sciences. The inaugural engineering graduates represented 40% women, 25% of students representing racial and ethnic minorities, first-generation students (~10%), international students (~10%), and student athletes (~10%). Pierrakos also led and implemented with the founding team an innovative and evidence-based hiring process to recruit a diverse faculty body (Pierrakos, 2025) and institute many evidence-based, theory-grounded, and research-based practices and strategies to curriculum design, advising, and innovation (Pierrakos, 2023; Pierrakos and Kenny, 2025) all strategically aligned to the "Educate the Whole Engineer" vision and mission.

Pierrakos' leadership during the inaugural years was marked by intensive team-building and visioning work with the founding faculty hires. Together, the founding team with invited campus experts and facilitators co-designed, co-envisioned, and co-taught. The founding team implemented project-based learning as the foundational pedagogical approach. A foundation was laid with five unique projects being introduce during the two-course first year experience where engineering practice was made visible for students via engineering design, engineering research, and engineering entrepreneurial thinking.

Innovative Curriculum Development Approach

In developing the curriculum, Pierrakos and the founding team took an unconventional "backward design" approach (Pierrakos, 2024), beginning with their vision of the ideal Wake Forest Engineering graduate and working backwards to design learning experiences that would develop these desired capabilities. Unlike traditional engineering programs with rigid disciplinary silos, they integrated content across disciplines—combining courses like statics, dynamics, materials, and mechanics into one integrated engineering course AND courses like thermodynamics, fluid mechanics, and heat transfer into one integrated engineering course, etc.

Not only was the curriculum structurally designed to be flexible and customizable - where about 60% of credits were predetermined, giving students agency over their educational path – but learning outcomes were intentionally integrated to bridge technical knowledge with professional competencies (Pierrakos, 2024). Student choice and student agency combined with curricular innovation and customization resulted in over 75% of graduates pursuing minors or second majors, demonstrating the success of this integrated approach in supporting disciplinary exploration while maintaining rigorous engineering preparation (Pierrakos and Kenny, 2025).

Wake Forest Engineering was launched with a commitment to student-centered pedagogies and experiential learning being a part of every engineering course. Faculty were hired with the expectation of leveraging student-centered pedagogies to bridge theory and practice via experiential learning in every engineering course. This expectation was communicated starting during the interview process and onboarding process as well as mentoring, reward structures, and the co-teaching model, all while ensuring alignment between faculty capabilities and program vision towards student success and flourishing.

III. IMPLEMENTATION MODEL: 100% EXPERIENTIAL LEARNING

The Wake Forest Engineering curriculum builds a comprehensive experiential learning experience through carefully sequenced courses, each incorporating hands-on and minds-on experiential projects that develop both technical and professional skills. The core curriculum comprises 33 credit hours of common knowledge and learning that all engineering students take, structured across four years of study:

Year 1: Foundation in engineering design and experimentation (EGR 111, EGR 112)
Year 2: Integrated approach to engineering science fundamentals (EGR 211, EGR 212)
Year 3: Advanced technical competencies & intro. to capstone design (EGR 311, 312, 313)
Year 4: Capstone design sequence focused on real-world projects (EGR 314, EGR 315)

This curriculum (**Figure 1**) represents a thoughtful progression from foundational skills to complex, real-world applications while maintaining focus on both technical competency and broader societal impact. The structure enables approximately 60% common knowledge experiences, with 40% reserved for specialized electives, concentrations, and customization.

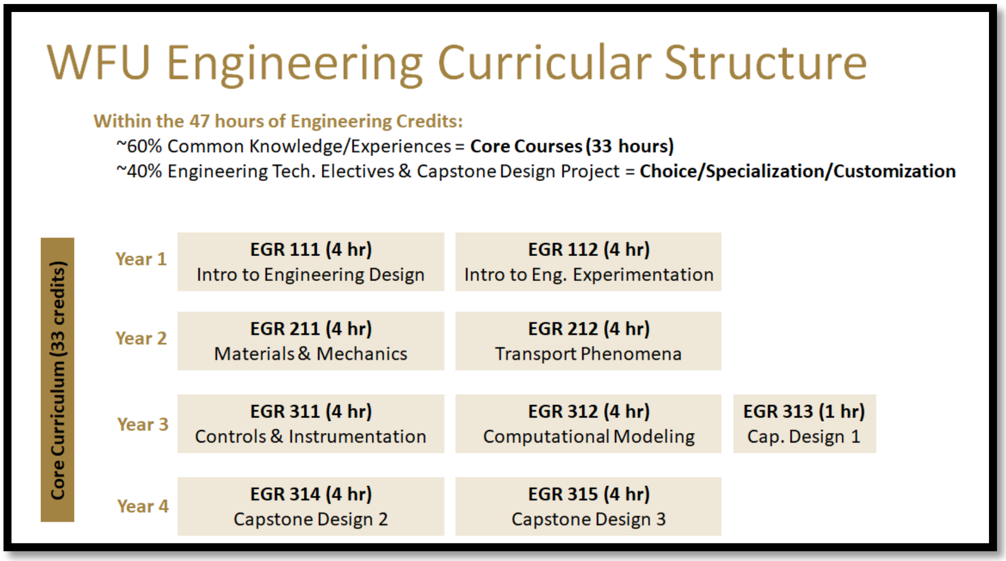

Figure 1: Visual representation of Wake Forest Engineering curriculum.

Pedagogical Diversity and Integration

A key feature of the Wake Forest Engineering curriculum is the intentional integration of multiple experiential learning pedagogies throughout the program (**Table 1**). Rather than relying on a single approach, the curriculum incorporates many as shown in **Table 1**. These pedagogies leverage both learning theories and motivational theories. These pedagogies are well grounded in engineering education as evidenced below.

- **Project-Based Learning (P_jBL) -** Project-based learning engages engineering students in complex, authentic challenges that mirror real-world engineering practice over extended periods. Students produce tangible outcomes (prototypes, designs, systems) that respond to genuine needs while navigating real-world constraints (Clancy, 2020). P_jBL naturally develops professional communication as students present their work to stakeholders and builds crucial teamwork capabilities (Aeikens, 2021). This approach aligns seamlessly with Kolb's experiential learning model, as students engage with concrete experiences through hands-on project work, practice reflection during reviews, develop abstract conceptualization through planning, and pursue active experimentation through implementation (Dukart, 2017).

- **Problem-Based Learning (P_bBL) -** Problem-based learning focuses on students collaboratively solving complex, ill-structured problems with multiple possible solutions. Originating from medical education at McMaster University in the 1960s, P_bBL emphasizes the problem-solving process rather than physical deliverables (Chen et al., 2021; Edstrom and Kolmos, 2014; Russell et al., 2010). Students analyze challenges like bridge failures, energy system optimization, or manufacturing defects, developing critical analytical skills and applying engineering principles to ambiguous situations. The approach progresses through stages paralleling Kolb's experiential learning cycle: encountering problems, engaging in group discussions, researching solutions, and testing implementation.

- **Design-Based Learning (DBL) -** Design-based learning centers on the iterative design process fundamental to engineering disciplines. Students identify needs, generate concepts, analyze alternatives, prototype, test, and refine solutions. Engineering DBL emphasizes creative thinking, constraints analysis, user considerations, and technical feasibility through projects like designing medical devices, sustainable buildings, or consumer products with specific performance requirements (Gomez et al., 2011; Strobel et al., 2013). This approach naturally incorporates experiential learning cycles as students move through phases of concept development, testing, reflection, and refinement.

- **Case-Based Learning (CBL) -** Case-based learning uses carefully selected real or simulated engineering scenarios that document successes, failures, ethical dilemmas, or complex decisions (Lavi and Martin, 2023; Vivas and Allada, 2006). Students analyze cases like the Challenger disaster or Three Mile Island incident to understand technical, ethical, and organizational factors. CBL is particularly effective for developing critical thinking and professional judgment (Thistlethwaite et al., 2012) by creating "vicarious experiences" that trigger cognitive processes similar to direct experience. The case approach promotes knowledge application and analytical reasoning while making technical content more accessible and memorable by embedding principles in compelling contexts (Tripathy, 2008).

- **Laboratory-Based Learning (LBL) -** Laboratory-based learning involves hands-on experimental work to verify principles, test hypotheses, collect and analyze data, and develop technical skills (Krivickas and Krivickas, 2007; Feisel and Rose, 2005). This approach continues to evolve, combining traditional hands-on experiences with modern technological innovations. Virtual and remote laboratories now complement physical experimentation, allowing students to investigate phenomena that would be inaccessible due to safety, scale, or resource constraints. Effective laboratory learning transcends procedural approaches by engaging students in designing experiments, analyzing unexpected results, and communicating findings.

- **Community-Engaged Learning (CEL) -** Community-engaged learning (service learning) connects engineering education with real community needs and partners. This approach combines meaningful community service with structured academic learning, developing civic awareness, problem-solving skills, and empathy (Natarajarathinam et al., 2021). Students might design assistive technologies for people with disabilities or develop sustainable solutions for underserved communities. Effective service learning involves genuine reciprocity—communities receiving valuable technical assistance while students gain contextual understanding. Success requires sufficient duration and carefully structured reflection activities.

- **Reflective Learning (RL) -** Reflective learning in engineering education involves structured reflection on experiences, decisions, and outcomes (Turns et al., 2014). Engineering students maintain design journals, write reflection papers on team dynamics, or analyze their problem-solving approaches. RL helps develop metacognitive skills, professional identity, and the ability to transfer learning to new engineering contexts. The reflection component is crucial across all experiential learning approaches, helping students examine not just technical questions but also ethical dimensions of engineering practice, including considerations of access, sustainability, and cultural appropriateness.

- **Team-Based Learning (TBL) -** Team-based learning structures engineering education around permanent student teams that collaborate on significant problems. Engineering programs use TBL to simulate professional practice where engineers rarely work in isolation. TBL in engineering develops communication skills, conflict resolution, distribution of technical tasks, and integration of diverse expertise—critical competencies for modern engineering practice. The collaborative nature of engineering projects helps students learn to leverage diverse perspectives and manage complex group dynamics, preparing them for workplace realities.

- **Self-Directed Learning (SDL) -** Self-directed learning gives engineering students significant autonomy in determining learning goals, resources, strategies, and assessment of outcomes (Litzinger et al., 2005). Engineering students might identify specialized technical areas to explore, develop personal learning plans, or pursue independent research. SDL prepares engineers for lifelong learning essential in a rapidly evolving technical field. This approach requires students to take ownership of their learning process, which Tembrevilla, Phillion, Zeadin (2024) identified as a key factor for success in experiential learning programs.

- **Flipped Classroom Learning (FCL) -** Flipped classroom learning in engineering inverts traditional instruction by delivering content outside class time through videos or readings, while dedicating class time to problem-solving, design activities, and application (Karabulut et al., 2018; Kerr, 2015; Lo and Hew, 2019). Engineering FCL maximizes valuable instructor-student interaction time for higher-order engineering skills rather than content delivery, particularly beneficial for complex technical concepts. This approach often incorporates technological tools for content delivery and assessment, adapting to accommodate remote and hybrid learning environments.

This pedagogical diversity creates a rich, multi-dimensional learning environment that supports different learning styles while developing a range of technical and professional competencies needed for engineering practice. Importantly, different pedagogies align with different learning and motivational theories, providing multiple pathways for student engagement and growth.

Project-based learning (P_jBL) and problem-based learning (P_bBL) are the most predominant experiential learning experiences in the engineering classroom (Tembrevilla, Phillion, & Zeadin, 2024). When implemented effectively and grounded in several complementary learning and motivational theories, Project-Based Learning (PjBL) can exemplify Kolb's Experiential Learning Theory by guiding students through complete learning cycles of concrete experience, reflection, conceptualization, and active experimentation. PjBL embodies constructivist principles as students build knowledge through creating and testing engineering solutions, while situated learning theory explains how projects effectively mirror authentic professional contexts. Motivationally, PjBL aligns with Self-Determination Theory (SDT) by satisfying students' needs for autonomy through project choices, competence through skill development, and relatedness through collaboration. It builds self-efficacy as students successfully complete challenging projects, while demonstrating the value and relevance of engineering knowledge in alignment with Expectancy-Value Theory (EVT). This theoretical integration explains why engineering PjBL effectively develops technical knowledge, design skills, and professional competencies through complex, authentic projects like renewable energy systems or smart infrastructure solutions, making it one of the most widely implemented experiential learning approaches.

Similarly but with distinct features, problem-based Learning (P_bBL) draws strength from multiple learning theories that explain its effectiveness in developing engineering competencies. Constructivism serves as a foundation as students actively build understanding through analyzing complex engineering problems, while Social Constructionist Theory (SCT) explains how collaborative problem-solving leverages group knowledge construction to reach deeper insights. Cognitive Apprenticeship principles are evident as students develop expert thinking patterns by confronting authentic engineering challenges under faculty guidance. From a motivational perspective, P_bBL aligns with Achievement Goal Theory (AGT) by emphasizing mastery of problem-solving processes rather than performance outcomes, encouraging deeper engagement with engineering principles. Attribution Theory (AT) explains how students develop internal, controllable attributions as they connect their problem-solving strategies to outcomes, building confidence in their engineering abilities. The approach naturally fosters intrinsic motivation as complex engineering problems stimulate curiosity and satisfaction in resolving challenges. In engineering education, P_bBL effectively develops analytical thinking through ill-structured problems like failure analysis, optimization challenges, or systems troubleshooting, making it particularly valuable for developing the critical analytical skills and application of engineering principles to ambiguous situations that characterize professional practice.

While the above pedagogies point to how experiential learning can be supported in the engineering classroom, it is important to recognize that other strategies exist to support experiential learning beyond the engineering curriculum via co-curricular and extra-curricular learning experiences. We highlight a few herein but will not focus on these as part of this paper. We also recognize that some of these experiential learning experiences below may have curricular elements or be integrated into engineering curricula.

- **Internships and Cooperative Education** These immersive workplace experiences apply technical knowledge to authentic tasks while developing professional identity. Successful programs feature structured mentorship, progressive responsibility, and reflection activities, creating synergies that enhance learning when integrated with coursework.

- **Study Abroad Experiences** These programs develop global competencies through international technical coursework or field-based projects. They cultivate cross-cultural communication, adaptability, and understanding of contextual engineering practice. Most effective when incorporating intentional design elements and structured reflection to help students process cultural differences.

- **Undergraduate Research** Students work with faculty on original investigations, developing research methodologies and specialized knowledge. These experiences cultivate curiosity, analytical thinking, and perseverance while demystifying research processes and informing decisions about graduate education.

- **Design Competitions** Structured challenges motivate learning through designing, building, and demonstrating solutions within constraints. The competitive and public demonstrations develop technical skills alongside teamwork, time management, and performance under pressure—capabilities difficult to develop through classroom instruction alone.

- **Industry-Sponsored Projects** Address authentic industry problems with real constraints and stakeholders. Beyond technical application, these develop client communication and project management skills. External accountability creates professional responsibility as students translate between academic and industrial contexts.

<u>Course-Specific Implementation Examples</u>

The integration of experiential learning across the Wake Forest Engineering curriculum is exemplified by specific projects and approaches in the core (required) courses. While **Table 2** shows some of the projects (PjBL) that have been part of the curriculum, the list below shows some of the **experiential learning experiences (projects, labs, cases, reflections)** across the curriculum and linked to our ABET Student Outcomes assessment process (**Table 3**).

EGR 111:

- **Truss Project** - Apply basic understanding of engineering statics principles in the context of a hands-on project.
- **Cardboard Design Project** - Design, prototype, build, and test a fully functional piece of cardboard furniture using CAD modeling, technical drawing, statics analysis, and cardboard building techniques.
- **Reverse Design Impact** - Disassemble a product to describe how design decisions affect the manufacturability, use, and societal impacts.
- **Individual Development Plan** - Solicit and summarize feedback on personal and professional goals from a variety of audiences and develop an action plan.
- **Pre-Modern Engineer** - Independently research a historical engineer or engineering artifact to explore engineering within different contextual settings and communicate findings.

EGR 112:

- **Experimental Pilot Testing** - Evaluate conceptual experimental design by conducting a pilot test and analyzing resulting data.
- **Sensing Project** - Apply electronic fundamentals to implement instrumentation to collect data and apply statistical analysis to that data.
- **Stormwater Project** - statistical analysis of data to determine flowrate, phosphorus concentration, nitrate, and E. coli concentration.
- **Teaming Contract** - draft a formal contract of team expectations and procedures, and reflect on individual and team performance.
- **Cover Letters, Resumes** - Develop and present a professional identity that aligns with one's personal and professional goals.
- **Applying for an Internship** - Student applies for an internship or summer research opportunity and reflects on how that relates to their personal and professional goals.

<u>Table 1</u>: Experiential learning across the core Wake Forest Engineering curriculum. P_jBL: project based learning, P_bBL: problem based learning, DBL: design based learning, CBL: case based learning, LBL: laboratory based learning, CEL: community engaged learning, RL: Reflective Learning, TBL: team-based learning, SDL: self-directed learning, FCL: flipped classroom learning, MBL: mastery based learning, SDT: self determination. Other motivational theories mapped to courses and informed grading structures.

COURSE	P_jBL	P_bBL	DBL	CBL	LBL	CEL	RL	TBL	SDL	FCL	MBL	SD	Founding Faculty Leaders
EGR 111: Intro to Eng. Design (4 hr)	X	X	X	X		X	X	X		X	X	X	Pierrakos, Barrella, Boatman, Gross, Kenny, Luthy
EGR 112: Intro to Eng. Experimentation (4 hr)	X				X	X	X	X			X	X	Barrella, Boatman, Gross, Young, Luthy
EGR 211: Materials & Mechanics (4 hr)	X	X	X		X	X		X				X	Boatman, Lutzweiler, Henslee
EGR 212: Transport Phenomena (4 hr)	X	X	X		X		X	X	X	X	X	X	Pierrakos, Lowman, Yazdani
EGR 311: Control Systems & Instrumentation (4 hr)	X		X		X			X			X	X	Luthy, Henslee
EGR 312: Computational Modeling (4 hr)	X	X		X			X	X				X	Lowman, Di Vittorio
EGR 313: Capstone Design I (1 hr)	X	X	X	X			X	X			X	X	Pierrakos, Bachman, Pappas
EGR 314: Capstone Design II (4 hr)	X	X	X	X	X	X	X	X	X	X	X	X	Pierrakos, Bachman, Pappas
EGR 315: Capstone Design III (4 hr)	X	X	X	X	X	X	X	X	X	X	X	X	Pierrakos, Bachman, Pappas

EGR 211:

- **Bridge Design Project** - Design of a static support structure accounting for safety, environmental, and economic considerations and outcomes.
- **Client Letter** - Write a letter to communicate findings with a client.
- **Suspension Bridge Design Project** - Design the size/shape of mechanical systems by considering applied loads/forces and analyzing the static load path throughout the object.
- **Materials Laboratory** - Analyze collected data to determine electrical conductivity of various metals and semiconductors and mechanical properties of various metals and polymers.

EGR 212:

- **Bernoulli Lab** - Conduct appropriate experimentation to collect thermal fluid system data, analyze the data, and use engineering judgment to compare system performance.
- **Hair Dryer Disassembly & Functional Model Lab** - Develop a functional model of an existing engineering system by performing product disassembly.
- **Thermal Fluid system Modeling Project** - Create a mathematical model using conservation principles of mass, momentum, and energy to characterize and analyze a real-world thermal fluid system.
- **End-of-Semester Reflection** - Review and reflect on individual performance in class including study habits, time management, and engagement and how these relate to efficiency, productivity, resilience, and motivation.
- **Course Project Report** - Research, analyze, and describe a novel real-world thermal-fluid engineering system using the knowledge, concepts, principles, and analysis methods learned in class.

EGR 311:

- **Circuit Design Final Project** - Design a circuit accounting for technical, economic, social, cultural, and safety factors.
- **Capacitor Lab** - Conduct appropriate experimentation and analysis to determine capacitor time constants and compare to theoretical values.
- **Power Module Project** - Identify and research a project idea of personal interest related to controls systems and instrumentation and develop an instructible for a novice audience.
- **Sensors Labs** - Design a basic circuit and apply coding algorithm to process sensor input/output.
- **Final Project Prototype** - Apply making techniques (e.g. 3D printing, laser cutting, sewing, etc.) to produce a physical prototype.
- **Wearable Electronic Device** - Design, prototype, build, test and instruct others on a wearable electronic device.
- **System Modelling and Controls Labs** - Perform PID control analysis on various systems to determine appropriate method of control with regards to settling time, overshoot, damping, and stability.

EGR 312:

- **Numerical Methods in Computational Modeling Final Project** - Apply numerical methods in a variety of engineering contexts and quantify numerical error, accuracy and efficiency.

- **Mathematical Model Testing Lab** - Conduct appropriate experimentation of mathematical models to generate results and analyze error.
- **Mathematical Model Testing Final Project** - Conduct appropriate experimentation of mathematical models to generate results and analyze error.
- **Problem Solving Lab Peer Review Reflection** - Reflect on the peer review process to identify areas of personal learning and document strategies and changes to implement on future assignments.
- **Final Project** - Formulate and solve engineering optimization problems, unconstrained and constrained, using numerical methods.
- **Journal Reflection** - student reflection on the development of a supercomputer being used to identify compounds potentially capable of treating COVID-19, and student reflection on how to minimize the harm of autonomous vehicles.

Capstone Course Sequence (EGR 313, EGR 314, EGR 315):

- **Design Project** - Complete a guided design project that covers the initial phases of the design process from gathering information, establishing design criteria, generating concepts, and analyzing possible solutions.
- **Independent Development Plan** - Considering purpose and authenticity, select and create a career artifact to support future aspirations.
- **Feasibility Analysis** - Evaluate potential design projects and assess their feasibility to be tackled throughout the yearlong capstone process.
- **Self and Peer Evaluation** - Give and receive performance-based feedback in written and oral format to other members of your capstone design team.
- **Agile Project Backlog and Schedule** - Plan a schedule for a team project organized around goals and prioritized tasks.
- **Risk Analysis Section of Final Design Report** - Demonstrate the use of risk analysis in the context of a design project and taking into account a multitude of risks.
- **Capstone Project Report Mathematical Modeling** - Identify, formulate, and solve appropriate analytical, mathematical, and numerical models using engineering, science, and mathematics principles to support decisions in an engineering design solution (capstone design project).
- **Capstone Design Report** - Design of an engineering solution (capstone design project) utilizing a systematic engineering design process and authentic engagement with stakeholders and considering technical, societal, economic, environmental, and global factors.
- **Prototype Testing and Validation** - Develop and apply testing protocols to measure design performance, and analyze testing results to evaluate design success and draw conclusions.
- **Capstone Project Impact Analysis** - Critically evaluate global, economic, environmental, and societal impacts of an engineering design solution (capstone design project).
- **Design Retrospective** - Individually reflect on one's own performance to date, conduct self-assessment, and apply reflection outcomes to facilitate team retrospectives and self-improvement goals.
- **Engineering Economics Analysis** - Understand basic engineering economic principles relevant to engineering practice.

- **Mathematical Modeling** - Apply mathematical modeling (or computational modeling) using engineering fundamental principles to justify/make decisions towards enhanced performance of the system being designed.
- **Failure Modes & Effects Analysis** - Perform a failure mode analysis to identify failures and frequency as well as propose strategies to mitigate effects of failure.
- **Commercialization Assessment** - Perform an assessment of commercialization potential and intellectual property implications in the context of the capstone project.
- **System Requirements Section of Final Report** - Apply engineering codes and standards to some aspect of design/prototyping process.
- **Embodiment Section of Final Report** - Apply engineering analysis and design tools to produce prototypes for evaluation.
- **Detailed Design Section of Final Report** - Apply engineering analysis and design tools to produce prototypes for evaluation.
- **Self and Peer Evaluation** - Give and receive performance-based feedback in written and oral format to other members of your capstone design team.
- **Faculty Coach Evaluation** - Solicit performance-based feedback from capstone project faculty coaches and instructional faculty.
- **Performance Feedback Solicitation** - Feedback from capstone project faculty coaches and instructional faculty.
- **Semester Goals & Project Schedule and Backlog** - Use Agile principles in the context of capstone design projects to identify project goals and deliverables, prepare a backlog and project schedule, prioritize tasks, and manage project progress and team productivity.
- **Project and Team Management Section of Final Design Report** - Document the use of Agile principles in the context of capstone design projects.
- **Career Readiness** - Complete a career readiness activity that supports students' job placement needs.
- **Design Review** - Solicit feedback via presenting capstone project progress and artifacts to a panel of technical experts in the format of a design review to inform future steps and decisions.
- **Final Capstone Design Report** - Prepare a technical design report to thoroughly document capstone project process, progress, artifacts, and decisions with a technical audience in mind.
- **Project Presentation** - Adapt project story to be understandable to a broad audience and deliverable across multiple modalities.
- **Prototype Showcase** - Adapt project story to be understandable to a broad audience and deliverable across multiple modalities.

This curriculum-wide integration ensures that students graduate with extensive project experience, professional capabilities, and a portfolio demonstrating their engineering competencies in authentic contexts.

<u>Table 2</u>: Subset of projects across the WFU Engineering curriculum and associated pedagogies.

Course	Subset of WFU Engineering Projects
EGR 111	**Truss Project**: Apply basic understanding of engineering statics principles in the context of a hands-on project. (P$_j$BL, DBL) **(Faculty Lead: Lutzweiler)**
	Cardboard Design Project: Design, prototype, build, and test a fully functional piece of cardboard furniture using CAD modeling, technical drawing, statics analysis, and cardboard building techniques. (P$_j$BL, DBL, TBL) **(Faculty Lead: Kenny, Luthy, Barrella, Gross)**
EGR 112	**Sensing Project**: Apply electronic fundamentals to implement instrumentation to collect data and apply statistical analysis to that data. Partners with campus and community stakeholders to understand the sensing needs. (P$_j$BL, LBL, TBL, CEL) **(Faculty Lead: Luthy)**
	Stormwater Project: Statistical analysis of data to determine flowrate, phosphorus concentration, nitrate, and E. coli concentration. There have been many variations to this project. (P$_j$BL, LBL, CEL) **(Faculty Leads: Boatman, Young, Di Vittorio)**
EGR 211	**Local Building Reverse Engineering Structures Project**: Reverse engineer existing structural system to determine original design criteria. (P$_j$BL, P$_b$BL, CBL, CEL) **(Faculty Lead: Lutzweiler)**
	Deck Design Project: Design the size/shape of system by considering applied loads/forces and analyzing the static load path. (PjBL, DBL, TBL) **(Faculty Lead: Lutzweiler)**
EGR 212	**Thermal Fluid System (Reverse Engineer and Modeling) Project**: Research, analyze, and reverse engineer a real-world thermal-fluid engineering system (of one's choosing) to create a mathematical model using conservation principles of mass, momentum, and energy to characterize the system to performance improvement. (PjBL, PbBL, SDL, FCL) **(Faculty Lead: Pierrakos)**
	Hair Dryer Reverse Engineering Project: Inexpensive hair dryer disassembly followed by hair dryer performance testing labs and diverse hair dryer comparisons and testing to understand design decisions impacting system performance. (P$_j$BL, P$_b$BL, DBL, LBL) **(Faculty Lead: Pierrakos)**
EGR 311	**Power Module Project**: Identify and research a project idea of personal interest related to controls systems and instrumentation and develop an instructible for a novice audience. (PjBL, SDL, RL) **(Faculty Leads: Luthy and Henslee)**
	ECG Project (Mid-term Project): Design passive and active filters, apply amplification, and design an algorithm based on signal requirements and desired outputs. (PjBL, LBL, DBL) **(Faculty Leads: Luthy and Henslee)**
	Wearable Electronic Device: Design, prototype, build, test and instruct others on a wearable electronic device. (PjBL, DBL, TBL, LBL, SDL) **(Faculty Leads: Luthy and Henslee)**
EGR 312	**Numerical Methods in Computational Modeling Project**: Apply numerical methods in a variety of engineering contexts and quantify numerical error, accuracy and efficiency. (PjBL, PbBL, SDL) **(Faculty Leads: Lowman and Di Vittorio)**
EGR 313 - 315	**Capstone Design Sequence:** Three-course progression (9 credits) using a four-phase design process (Discovery, Conceptual, Embodiment, Detailed). Students work in teams with faculty coaches on real-world projects. Integrates design competencies with team effectiveness, entrepreneurial mindset, and character development through cognitive apprenticeship framework. (PjBL, PbBL, DBL, CBL, TBL, CEL, RL, SDL) **(Faculty Leads: Pierrakos, Bachman, Pappas)** (Pierrakos et al., 2024)

Table 3: Other experiential learning experiences mapped to the ABET Student Outcomes and used in program-level assessment.

Course	SO1	SO2	SO3	SO4	SO5	SO6	SO7
EGR 111	Statics Exercises, Thermal Concept Questions, Static Loading Exercises, Coding Exercises, Truss Project, Coding Project	Cardboard Design & Build Project, Product Disassembly, CAD Drawing, Design Process Concept Qs	Cardboard Design Project Report, Pre-Modern Engineer	Reverse Design Impact, Interview an Engineer			Individual Development Plan, Pre-Modern Engineer, Interview an Engineer
EGR 112	Electronics Exercises, Vectors and Kinematics Homework	Stormwater Project, Comprehensive budget for research design	Final Project Research Proposal, Extended Abstract, Project Research Proposal Oral Presentation	Connecting Humanities with Engineering	Teaming Contract, Teaming Module, Peer Team Evaluation, Teamwork Reflection	Laboratory Safety, Data Acquisition, Statistical analysis of Experimental Data, Experimental Analysis & Data Synthesis, Sensing Project	Cover Letters, Resumes, Applying for an Internship, Background Research
EGR 211	Statics & mechanics portion of the final exam, Dynamics portion of the final exam	Beam Design, Bridge Design Project, Reverse Engineering, Suspension Bridge Design Project, Deck Design Project	Engineering Letter to Client	Ethic Case Studies		Materials Laboratory Experiment	
EGR 212	Thermodynamics Concept Questions, Fluid statics and Thermodynamics Exercises, Fluid momentum and Mechanical Energy Exercises, Thermal-fluids Problems	Reverse Engineering a Hair Dryer, Hair Dryer Disassembly & Functional Model Lab, Reverse Engineering Concept Questions	Lab Report Oral Presentations, Bernoulli Lab Report, Course Project Report, Course Project Presentation	Course Project Report, In-Class Activity and Discussion	Team Member Effectiveness Reflection	Viscosity Lab, Hydrostatic Forces, Density Lab, Hair Dryer Conservation of Energy Lab, Reverse Engineering a Hair Dryer	Course Project Report, End-of-Semester Reflection, Resilience module mid-semester reflection and action plan, Resilience Module End-of-Semester Reflection

Course	SO1	SO2	SO3	SO4	SO5	SO6	SO7
EGR 311	Circuits and Instrumentation Workout Exam Problems, Circuits & Controls Concept Questions, AC/DC Exercises, Final Theoretical Exam	Circuit Design Final Project, Circuit Design Concept Questions, Mid-Term Practical Exam, Sensors Labs, Final Project Prototype	ECG Webpage, Power Module Project Webpage, Research Project Oral Presentation		Backlog for Final Project, Digital Mini Project Peer Evaluation Form, Project Team Planning Assignment, Project Team Evaluation and Reflection Assignment	Capacitor Lab, Laboratory Experiment, Lab, Week 2 Lab A-B Deliverables, System Modelling and Controls Labs, Mid-Term Practical Exam	Power Module Project, Power Module Project Reflection
EGR 312	Error & Uncertainty Exercises, Root Finding Methods, Regression Models, Numerical Methods in Computational Modeling Project	Final Coding Project, Regression Models Alternative Approach	Final Project Websites, Final Project Peer Review, Problem Solving Lab, Journal Reflection	Journal Reflection, Modeling Impact Journal Entry		Mathematical Model Testing Lab, Mathematical Model Testing Project, Error Analysis of Project	Quality of Response Section of Final Project, Reflection Section of Problem Solving Lab, Quality of Response for Journal
EGR 314	Practice taking the Fundamentals of Engineering (FE) exam via quizzes and one practice exam	Feasibility Analysis of Top 4 Project Proposals, Discovery Design and Conceptual Design Concept Questions	System Requirements Review – Design Report	Ethical Frameworks, Empathy as a Virtue Discussion	Design Team Contract, Conceptual Design Backlog, Team Role and Work Agreement, Self and Peer Evaluation	Feasibility Analysis of Top 4 Project Proposals	Creativity as a virtue, Independent Development Plan
EGR 315	Capstone Report Mathematical Modeling, Engineering Economics, Mathematical Modeling	Capstone Design Report, Failure Modes & Effects Analysis, Commercialization Assessment, Detailed Design Report	Capstone Final Design Report	Capstone Project Impact Analysis, Ethical Leadership	Team Retrospective & Work Agreement, Team Contract, Self & Peer Evaluation, Faculty Coach Evaluation, Performance Feedback Solicitation, Goals & Project Schedule	Prototype Testing and Validation	Career Readiness

Theoretical Alignment and Assessment Integration

Aligning experiential learning with theories of learning and student motivation is essential. Both at Wake Forest Engineering and across engineering education, Project-based learning (P_jBL) and problem-based learning (P_bBL) are the most predominant experiential learning experiences in the engineering classroom (Tembrevilla, Phillion, & Zeadin, 2024). When implemented effectively and grounded in several complementary learning and motivational theories, Project-Based Learning (PjBL) can exemplify Kolb's Experiential Learning Theory by guiding students through complete learning cycles of concrete experience, reflection, conceptualization, and active experimentation. PjBL embodies constructivist principles as students build knowledge through creating and testing engineering solutions, while situated learning theory explains how projects effectively mirror authentic professional contexts. Motivationally, PjBL aligns with Self-Determination Theory (SDT) by satisfying students' needs for autonomy through project choices, competence through skill development, and relatedness through collaboration. It builds engineering self-efficacy as students successfully complete challenging projects, while demonstrating the value and relevance of engineering knowledge in alignment with Expectancy-Value Theory (EVT). This theoretical integration explains why engineering PjBL effectively develops technical knowledge, design skills, and professional competencies through complex, authentic projects like renewable energy systems or smart infrastructure solutions, making it one of the most widely implemented experiential learning approaches.

Similarly but with distinct features, problem-based Learning (P_bBL) draws strength from multiple learning theories that explain its effectiveness in developing engineering competencies. Constructivism serves as a foundation as students actively build understanding through analyzing complex engineering problems, while Social Constructionist Theory (SCT) explains how collaborative problem-solving leverages group knowledge construction to reach deeper insights. Cognitive Apprenticeship principles are evident as students develop expert thinking patterns by confronting authentic engineering challenges under faculty guidance. From a motivational perspective, P_bBL aligns with Achievement Goal Theory (AGT) by emphasizing mastery of problem-solving processes rather than performance outcomes, encouraging deeper engagement with engineering principles. Attribution Theory (AT) explains how students develop internal, controllable attributions as they connect their problem-solving strategies to outcomes, building confidence in their engineering abilities. The approach naturally fosters intrinsic motivation as complex engineering problems stimulate curiosity and satisfaction in resolving challenges. In engineering education, P_bBL effectively develops analytical thinking through ill-structured problems like failure analysis, optimization challenges, or systems troubleshooting, making it particularly valuable for developing the critical analytical skills and application of engineering principles to ambiguous situations that characterize professional practice.

Although it is beyond the scope of this paper to detail the integration of learning theories and motivational theories for each course within the Wake Forest Engineering curriculum, I highlight a few here:

Among the motivational frameworks that particularly align with experiential learning, Achievement Goal Theory provides special insights into designing effective learning environments. As demonstrated by Pierrakos, Yazdani, and Koehler (2024), classrooms that promote mastery goal orientation—focusing on mastering new knowledge and skills to increase understanding and competence—rather than performance goal orientation (focusing on achievement through external recognition) yield distinctive benefits beyond technical competence. Their research in a thermal-fluids engineering course revealed that mastery-based learning approaches cultivated important character virtues including resilience, courage, humility, and critical thinking. This connection between pedagogical approach and character development suggests that experiential learning environments can simultaneously develop technical and professional competencies while fostering the virtues essential for ethical engineering practice.

The Wake Forest Engineering capstone experience that Pierrakos co-led successfully integrates cognitive apprenticeship, project-based learning, and motivational theories into a comprehensive educational framework. Cognitive apprenticeship's six phases (modeling, coaching, scaffolding, articulation, reflection, and exploration) provide the structure for transferring expertise, while project-based learning creates authentic contexts through real-world engineering challenges. These approaches align with self-determination theory by fostering autonomy through increased independence, competence through scaffolded challenges, and relatedness through team-based work. The program balances achievement goal orientations by valuing process over product (mastery orientation) while maintaining accountability through design reviews (performance elements). This integration effectively supports "Educating the Whole Engineer" by addressing both technical competencies and non-technical aspects like character development, entrepreneurial mindset, and team effectiveness, though the authors acknowledge ongoing challenges in fully implementing certain phases, particularly modeling and reflection.

Table 4 shows these connections between engineering education pedagogies (supporting experiential learning) mapped to learning theories and motivational theories. *Constructivism* underlies nearly all experiential pedagogies in engineering education, emphasizing active knowledge construction rather than passive reception. This is particularly evident in problem, project, and design-based approaches where students must build understanding through experience. *Kolb's Experiential Learning Theory* provides a comprehensive framework for understanding how concrete experiences in laboratories, projects, and community settings transform into professional knowledge through reflection, conceptualization, and application. *Situated Learning Theory* explains why authentic contexts (community projects, design challenges, realistic cases) lead to more transferable learning than decontextualized instruction, particularly important in a practice-oriented field like engineering. *Social Constructionist Theory* highlights the critical role of collaborative learning in engineering education, explaining the effectiveness of team-based approaches in developing both technical and professional skills.

Along with learning theories, motivational theories further complement how educators can design effective experiential learning experiences. *Self Determination Theory* explains why experiential approaches in engineering education typically increase engagement—they satisfy basic psychological needs for autonomy, competence, and relatedness that traditional lecture-based instruction often neglects. *Self-Efficacy Theory* illuminates how hands-on successes in projects, labs, and design challenges build confidence in engineering capabilities, leading to greater persistence in the face of challenging coursework and technical obstacles. *Expectancy-Value Theory* clarifies why authentic engineering tasks increase motivation—they demonstrate the real-world value of theoretical concepts that might otherwise seem abstract or irrelevant. *Interest Development Theory* helps explain how initial situational interest triggered by novel engineering challenges can develop into enduring individual interest in engineering disciplines through sustained engagement with meaningful content.

Here are examples of experiential learning in engineering that connect learning theories and motivational theories:

1. **Comprehensive Design Projects** often integrate multiple pedagogies (PjBL, DBL, TBL, RL) and draw from multiple theories (Kolb, Constructivism, Self-Determination, Self-Efficacy) to create holistic learning experiences.
2. **Engineering Service Learning** combines CEL, PjBL, and TBL approaches, leveraging situated learning, communities of practice, and self-determination theories to develop both technical and professional skills while addressing community needs.
3. **Laboratory Courses with Design Components** integrate LBL and DBL approaches, building on Kolb's theory, constructivism, and self-efficacy to connect theoretical principles with practical applications.
4. **Case-Based Problem Solving** combines CBL and PbBL approaches, drawing from transformative learning, situated learning, and expectancy-value theories to develop engineering judgment and ethical reasoning.
5. **Flipped Design Studios** combine FCL, DBL, and RL approaches, leveraging constructivism, cognitive apprenticeship, and flow theory to maximize high-value interactions around complex design challenges.

Effective engineering education should intentionally align pedagogical approaches with learning and motivational theories to maximize student engagement and learning outcomes. Different pedagogies can target different aspects of engineering education and the integration of complementary approaches provides more comprehensive development of technical and professional competencies. Engineering educators explicitly considering motivational factors when designing learning experiences means that they are recognizing that motivation significantly impacts persistence and achievement in challenging technical fields. Across all pedagogies, structured reflection emerges as a critical component for transforming experience into learning, suggesting the need for intentional reflection activities in engineering education. Last but not least, the social aspects of learning highlight the importance of collaborative learning in preparing students for team-based engineering practice. **Figure 2** represents the five essential dimensions to supporting effective experiential learning experiences.

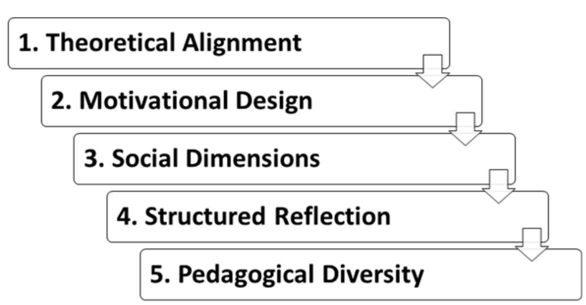

Figure 2: Five critical dimensions to designing effective experiential learning experiences.

The most effective engineering education approaches typically combine multiple pedagogies and leverage multiple theoretical foundations. For example, capstone design courses often integrate project-based learning (P_jBL), design-based learning (DBL), team-based learning (TBL), and reflective learning (RL) to create comprehensive experiences. Service-learning in engineering combines community engagement (CEL) with project-based approaches (P_jBL), drawing from situated learning theory, constructivism, and self-determination theory. Modern laboratory education often incorporates problem-based elements (P_bBL) and reflective components (RL) alongside traditional experimentation (LBL). This theoretical integration helps explain why multi-faceted experiential approaches are often more effective than single-strategy methods in developing well-rounded engineering graduates with both technical and professional competencies. Engineering education is particularly effective when pedagogical approaches are deliberately aligned with their theoretical foundations. For example, Design-Based Learning is enhanced when instructors consciously incorporate the cognitive apprenticeship model to make expert thinking visible. This mapping provides a theoretical framework for designing integrated engineering education experiences that leverage multiple learning and motivational mechanisms simultaneously.

Assessment methods were carefully chosen to align with the experiential learning approaches, using authentic assessment methods that mirror professional practice. The program mapped experiential learning experiences directly to ABET Student Outcomes, creating a direct connection between experiential learning and program assessment. This integration ensures that experiential learning isn't just an educational enhancement but the primary vehicle for achieving program learning outcomes.

The connection between experiential learning approaches and character development is particularly evident in Wake Forest's mastery-based learning implementations. Research by Pierrakos, Yazdani, and Koehler (2024) in a sophomore-level thermal-fluids course demonstrated that student-centered, mastery-based learning environments fostered specific character virtues essential for engineering practice. Our study revealed that students perceived development in virtues such as resilience (through persisting despite challenges), courage (through attempting difficult problems after initial failure), and humility (through recognizing knowledge limits and seeking help). This evidence suggests that experiential learning not only develops technical competencies but simultaneously cultivates the character dimensions needed for ethical engineering practice.

Table 4: Mapping of engineering education pedagogies (supporting experiential learning) to learning and motivational theories.

Engineering Education Pedagogy	Primary Supporting Learning Theories	Primary Supporting Motivational Theories
Project-Based Learning (PjBL)	• Kolb's Experiential Learning Theory • Constructivism • Situated Learning Theory • Communities of Practice	• Self-Determination Theory • Self-Efficacy • Expectancy-Value Theory • Flow Theory
Problem-Based Learning (PbBL)	• Constructivism • Social Constructionist Theory • Cognitive Apprenticeship Theory	• Achievement Goal Theory • Attribution Theory • Intrinsic Motivation • Interest Development Theory
Design-Based Learning (DBL)	• Cognitive Apprenticeship Theory • Constructivism • Kolb's Experiential Learning Theory	• Flow Theory • Self-Efficacy • Interest Development Theory • Intrinsic Motivation
Case-Based Learning (CBL)	• Transformative Learning Theory • Situated Learning Theory • Social Constructionist Theory • Cognitive Apprenticeship Theory	• Expectancy Value Theory • Attribution Theory • Situational Interest Theory • Social Cognitive Theory
Laboratory-Based Learning (LBL)	• Kolb's Experiential Learning Theory • Constructivism • Cognitive Apprenticeship Theory • Situated Learning Theory	• Self-Efficacy • Intrinsic Motivation • Flow Theory • Expectancy Value Theory
Community-Engaged Learning (CEL)	• Situated Learning Theory • Communities of Practice • Transformative Learning Theory	• Self-Determination Theory • Expectancy Value Theory • Interest Development Theory • Goal Setting Theory
Reflective Learning (RL)	• Transformative Learning Theory • Kolb's Experiential Learning Theory • Self-Directed Learning Theory	• Attribution Theory • Self-Efficacy • Achievement Goal Theory • Self-Determination Theory
Team-Based Learning (TBL)	• Social Constructionist Theory • Communities of Practice • Situated Learning Theory	• Self-Determination Theory • Social Cognitive Theory • Expectancy Value Theory • Attribution Theory
Self-Directed Learning (SDL)	• Self-Directed Learning Theory • Constructivism • Transformative Learning Theory	• Self-Determination Theory • Intrinsic Motivation • Interest Development Theory
Flipped Classroom Learning (FCL)	• Constructivism • Cognitive Apprenticeship Theory • Social Constructionist Theory • Kolb's Experiential Learning Theory	• Self-Efficacy • Self-Determination Theory • Expectancy Value Theory • Intrinsic Motivation

IV. CHANGE MANAGEMENT STRATEGIES

Implementing 100% experiential learning across the Wake Forest Engineering curriculum required a systematic and strategic approach to organizational change. Kotter's Eight-Step Change Model provided an effective framework for this transformation:

Step 1: Creating Urgency

The creation of a new engineering program presented a unique opportunity to establish experiential learning from the beginning. The team leveraged available exemplar programs, STEM education research, ABET requirements, and industry advisory board feedback to demonstrate the need for comprehensive experiential learning. Key strategies included:

- Presenting to the founding team what industry demands of engineering graduates
- Highlighting the gap between traditional engineering education and professional practice
- Sharing evidence of experiential learning's impact on student outcomes and retention
- Demonstrating how peer institutions are successfully implementing experiential approaches
- Presenting accreditation requirements that align with experiential learning
- Highlighting that the top ranked engineering program incorporated experiential learning
- Showcasing that experiential learning was a vehicle to build partnerships across campus and within our local community and advocacy for our new program

Step 2: Building a Guiding Coalition

Successful implementation required coordination across multiple domains. The founding team served as the initial coalition, bringing diverse expertise in various engineering disciplines, educational research, and pedagogical innovation. This coalition was expanded to include:

- Inviting students to be partners in the co-creation of the learning environment and sourcing feedback from students
- Inviting pedagogy experts (external and internal) for faculty development
- Bringing experiential learning experts to support the founding team
- Engaging industry advisory members
- Establishing an external advisory council
- Pulling in laboratory and makerspace staff to be part of curricular discussions
- Inviting educational technology specialists to be part of the team
- Hiring assessment experts to support the curriculum and the faculty
- Student representatives as advocates
- Promoting and rewarding a scholarly approach to engineering education
- Inviting faculty to share knowledge around successes and failures
- Supporting internal and external faculty development activities
- Assigning or inviting experienced faculty (with pedagogy experience and experiential learning experience) mentor or co-teach with less experienced faculty (e.g. junior) who had less experience with student centered pedagogies
- Making teaching assignments to match experienced faculty with less experienced faculty

- Joined in KEEN network in 2018 who became an essential partner for faculty development. Nearly 100% of WFU engineering faculty participated in KEEN-sponsored faculty development workshops. This was an essential partnership considering WFU's Center for the Advancement of Teaching offered limited offerings for STEM faculty.

Step 3: Forming Strategic Vision and Initiatives

We carefully mapped how experiential learning would progress from fundamental skills to complex applications, developing a four-year developmental model. As we were building the curriculum from scratch, we were thinking about developmental learning and mapping out learning outcomes for each course, for each academic year, and for the full curriculum.

- Year 1: Basic design projects and fundamental engineering knowledge with team projects
- Year 2: Structured laboratory experiences via independent and team experiences
- Year 3: Advanced technical projects and specialized applications
- Year 4: Industry-sponsored, industry-involved, and stakeholder-driven capstone experiences

To develop a vision for experiential learning integration, we did the following:

- Defined what successful experiential learning looks like across all four years
- Benchmarked against other programmatic examples (even international ones)
- Created progression maps showing how projects and learning build through the curriculum
- Identified key competencies developed through experiential learning
- Planned infrastructure needs (laboratories, project spaces, studios, equipment)
- Established assessment frameworks aligned with learning outcomes

Step 4: Enlisting a Volunteer Army

Faculty development, team teaching, and positive student feedback were leveraged to expand support beyond the initial coalition. The key was to expand support beyond the initial coalition and use the following strategies:

- Joining national networks offering faculty development support and faculty peer mentoring activities including an annual conference to convene engineering educators (e.g. KEEN)
- Creating faculty learning communities around experiential pedagogy
- Developing peer mentoring networks through diverse team-teaching teams
- Training faculty in experiential learning methods by bringing pedagogical experts
- Engaging teaching assistants and lab coordinators to support the faculty
- Partnering with industry mentors and community partners for projects (over 50+ partners)
- Hiring student teaching assistants who served as program ambassadors
- Diversified the teaching teams and enlisted "committed" faculty to mentor "uncommitted" ones all modeled by the Founding Chair (Pierrakos) teaching across the curriculum
- Inviting community partners and industry partners to share project ideas that could be part of the curriculum (e.g. School of Medicine, industry, non-profits, local engineers)

Step 5: Enabling Action by Removing Barriers

I knew that I needed to rethink the reward structures for the young faculty team and we needed to facilitate knowledge sharing across courses and the curriculum. As the Chair, I also needed to demonstrate that failures with experiential learning would not be punished and I communicated that even when course evaluations were lower than expected. We also worked to streamline assessments to enable widespread adoption. Other strategies used to enable action by removing barriers included the following:

- Creating flexible classroom and laboratory spaces to support experiential learning
- Providing faculty development resources and time during department meetings to discuss challenges, successes, and opportunities
- Establishing course level budgets for equipment purchases and funding mechanisms to support experiential learning
- Updating assessment methods to match experiential learning
- Revised faculty performance metrics and rubrics and policies to incentivize and rewards attempts and implementation of new pedagogies and experiential learning
- Invited partners (internal and external) to showcase experiential learning opportunities and invite faculty to integrate into coursework and student experiences
- Designed assessment methods to match and promote experiential learning as the means to showcase exemplary learning
- Mapped experiential learning exemplar activities to required ABET/accreditation/assessment efforts
- Enlisting a team of industry-experienced faculty to streamline procedures for industry partnerships
- Recruited more advanced teaching assistants (e.g. graduate students from other programs) to support faculty with project management

Step 6: Generating Short-Term Wins

The program created a departmental culture where psychological safety supported experimentation with new pedagogies. Successes were celebrated with students through project showcase days, and successful implementations were highlighted to build momentum. It was also important to celebrate successes together and with our students via project celebration days and project showcase days. Other strategies we used to generate short-term wins included the following:

- Start with pilot projects and slowly scale up (encourage smaller efforts)
- Document and share successful implementations
- Encourage dissemination of successes and experiential learning efforts
- Hired postdocs to help the faculty assess learning and support course design
- Recognize faculty innovation in experiential teaching
- Highlight student achievements in projects
- Demonstrate improved learning outcomes
- Share positive partner (e.g. industry, community, university) feedback

Step 7: Sustaining Acceleration

The program built momentum through systematic expansion over the multi-year implementation period, gradually expanding the scope and complexity of experiential learning from foundational experiences to advanced applications.

Year 1:	- Implement foundational projects in introductory courses - Establish basic maker spaces and project areas - Begin faculty training programs and use the first year to onboard new hires
Year 2:	- Expand to intermediate courses - Enhance laboratory and project facilities - Develop industry and community partnership network
Year 3:	- Integrate advanced project experiences - Implement comprehensive assessment systems - Establish cross-disciplinary project opportunities
Year 4:	- Launch capstone with diverse partners (e.g. community, industry, non-profits) - Create sustainable support structures - Build long-term industry and community partner relationships

Step 8: Instituting Change

To embed experiential learning permanently across the curriculum, the following strategies were used to support institutionalizing experiential learning across the curriculum:

- Updated curriculum documentation and requirements
- Revised faculty evaluation criteria to value experiential teaching
- Established permanent support staff positions
- Created handbooks and resources for new faculty
- Built mentoring systems for continued faculty development
- Created transparent and sustainable funding mechanisms to support experiential learning
- Built experiential learning into program marketing and student recruitment and tours
- Developed ongoing assessment and improvement processes
- Emphasized experiential learning in promotion and reappointment processes of faculty
- Maintained consistent communication about progress and impact
- Provided ongoing support and resources and mentoring for faculty
- Continued gathering and sharing evidence of effectiveness
- Keep project partners actively engaged
- Solicited feedback and regularly assess and adjust implementation strategies
- Celebrated and recognized publicly successful innovations
- Built support systems that outlast individual champions

This structured approach helps ensure that experiential learning becomes deeply embedded in the engineering curriculum rather than remaining a series of isolated initiatives.

Leader Character Dimensions Supporting Change

While Kotter's change model provides Pierrakos insight into the attributes needed to successfully lead change, there is another framework that was influential in leading change in higher education and Wake Forest Engineering. Mary Crossan's ***Leader Character Framework*** (Crossan et al., 2017; Crossan et al., 2022) offers a complementary lens that enhances our understanding of organizational change theories to successfully lead change initiatives. For example, to complement Kotter's Eight-Step Change Model, the Leader Character Framework provides insight into the character qualities leaders need to execute each step effectively. While Kotter focuses on the process of change (creating urgency, building coalitions, generating wins), Leader Character —particularly courage, drive, accountability, and collaboration—explain why certain leaders successfully navigate these steps while others struggle. For instance, the courage dimension helps leaders overcome resistance when establishing urgency, while collaboration supports building effective guiding coalitions. Knowing that innovations spread through social systems, the Leader Character Framework illuminates the character qualities that make early adopters and change agents effective. The judgment, courage, and transcendence dimensions explain why certain individuals become influential early adopters of experiential learning approaches, willing to take calculated risks and maintain perspective during implementation challenges. Leaders with strong character can more effectively frame experiential learning initiatives in terms of educational equity and student success, mobilize resources through trusted relationships, and leverage political opportunities through principled engagement with stakeholders. Leaders who possess humility recognize the limits of their knowledge in complex systems and remain open to emergent solutions, while transcendence helps them maintain perspective during the non-linear, often messy process of implementing experiential learning programs. Together with Kotter's change model, the Leader Character Framework enabled Pierrakos to think of the benefits to the students and society as motivation for instituting experiential learning. Character dimensions enable the organizational learning capabilities that sustain experiential learning initiatives. In essence, Crossan's Leader Character Framework addresses a crucial gap by explaining why certain individuals successfully lead change while others falter despite following similar processes.

Table 5 demonstrates these connections between Kotter's change model and Leader Character dimensions. This table illustrates how the Leader Character Framework provides a complementary perspective to established change theories by identifying the specific character dimensions that enable leaders to successfully implement change with experiential learning initiatives. The successful implementation of experiential learning across the Wake Forest Engineering curriculum was supported by specific leader character dimensions that enabled effective change management:

- **Courage** was essential for creating urgency, challenging established educational norms, and taking calculated risks with innovative pedagogies.

- **Drive** provided the energy and persistence necessary to implement and sustain the changes, particularly when facing inevitable challenges and setbacks.

- **Collaboration** enabled the formation of effective guiding coalitions, team teaching arrangements, and knowledge-sharing networks essential for program success.
- **Judgment** informed the strategic decision-making required to align experiential learning with program learning outcomes and resource constraints.
- **Accountability** ensured follow-through on commitments to experiential learning, even when implementation required additional effort and resources.
- **Humility** supported openness to ongoing learning and adaptation, recognizing that implementing experiential learning is itself a learning process.
- **Transcendence** provided perspective during challenges, connecting daily implementation details to the larger vision of transforming engineering education.

The integration of these character dimensions with Kotter's change model created a powerful framework for leading the transformation to 100% experiential learning.

Table 5: Connecting Kotter's 8-Step Change Model with Crossan's Leader Character Framework

Kotter's Change Step	How Key Leader Character Dimensions Support the Change Step
1. Create a Sense of Urgency	• **Courage**: Honestly communicating challenges and risks • **Drive**: Providing energy and motivation to initiate change • **Judgment**: Accurately assessing situations and communicating appropriate urgency
2. Build a Guiding Coalition	• **Collaboration**: Bringing together the right mix of skills and influence • **Humanity**: Connecting authentically with potential coalition members • **Humility**: Recognizing the need for diverse perspectives and talents
3. Form a Strategic Vision	• **Judgment**: Creating viable strategic direction • **Transcendence**: Developing inspiring, future-oriented thinking • **Integrity**: Ensuring vision aligns with organizational values
4. Enlist a Volunteer Army	• **Drive**: Energizing and motivating broader organization • **Humanity**: Connecting with followers' needs and concerns • **Collaboration**: Building broad support networks across divisions
5. Enable Action by Removing Barriers	• **Courage**: Challenging established systems and processes • **Justice**: Ensuring fair treatment during change processes • **Accountability**: Taking responsibility for removing obstacles
6. Generate Short-Term Wins	• **Drive**: Persisting to achieve early visible successes • **Judgment**: Identifying strategic wins to pursue first • **Temperance**: Balancing short-term achievements with long-term goals
7. Sustain Acceleration	• **Drive**: Maintaining momentum throughout extended change • **Accountability**: Ensuring continued focus on commitments • **Temperance**: Preventing change fatigue by pacing initiatives
8. Institute Change	• **Integrity**: Embedding changes authentically in culture • **Transcendence**: Connecting changes to higher purpose • **Accountability**: Establishing ownership of new ways of working

V. ASSESSMENT AND OUTCOMES

Wake Forest Engineering developed a comprehensive assessment approach for experiential learning that aligned with ABET accreditation requirements while capturing the unique benefits of experiential education. Assessment activities will be part of a future paper. Key assessment methods though included:

- **Authentic Project Assessments:** Rubrics evaluated both process and product dimensions of student projects, including technical competence, design thinking, teamwork, and professional communication.

- **Reflective Writing:** Structured reflections helped students process their experiences and document their growth in both technical and professional domains.

- **Stakeholder Feedback:** Input from community partners, industry representatives, and other external stakeholders provided valuable assessment of student performance in authentic contexts.

- **Peer Evaluations:** Team members assessed individual contributions to collaborative projects, providing insight into teamwork capabilities.

- **Technical Competency Testing:** Traditional assessments verified mastery of fundamental engineering principles that students applied in experiential contexts.

These assessment methods were directly mapped to the seven ABET Student Outcomes, creating clear connections between experiential learning activities and accreditation requirements. Below we highlight some initial positive impacts of student development in the context of experiential learning at Wake Forest Engineering.

Communication and team skills see substantial enhancement through experiential learning approaches. These improvements extend beyond immediate academic settings, contributing to long-term professional success. Experiential learning enhances communication skills by requiring students to communicate with diverse audiences. Students learn to adapt their communication style and content based on whether they're speaking to peers, supervisors, clients, or community members. This adaptability is crucial for professional success. The authentic contexts in experiential learning provide immediate feedback on communication effectiveness. When a team member misunderstands instructions or a client is confused by a presentation, students experience real consequences and learn to improve their communication strategically. Experiential learning develops crucial team skills through sustained collaborative work on complex problems. Students learn to establish team norms, distribute responsibilities, coordinate efforts, and navigate team dynamics—practical skills that traditional classroom learning rarely addresses adequately. The open-ended nature of experiential learning projects requires teams to practice decision-making, conflict resolution, and negotiation skills. When multiple solutions are possible and stakes are real, students must learn to build consensus, leverage diverse perspectives, and resolve disagreements constructively. Some of our previous publications demonstrate these positive impacts (Pierrakos et al., 2024; Brock et al. 2024; Koehler et al. 2023; Gross et al., 2021).

Professional identity development through experiential learning represents a particularly meaningful outcome. When students participate in authentic experiential learning experiences, they begin to see themselves as emerging professionals rather than just students. This situated learning allows them to observe professional norms, adopt professional language, and understand the culture of their chosen field firsthand (Pierrakos et al., 2024; Kenny, Pierrakos, O'Donnell, 2021). Through experiential learning, students engage in legitimate peripheral participation—gradually taking on more professional responsibilities under supervision. This progressive involvement helps them internalize professional values and ethical standards while developing confidence in their professional capabilities. The reflective practices central to experiential learning facilitate professional identity formation by encouraging students to examine how their experiences align with their evolving professional self-concept. This reflection often involves questioning assumptions, reconciling personal values with professional expectations, and integrating various aspects of professional knowledge into a coherent professional identity. Mentorship relationships developed during experiential learning experiences provide crucial support for professional identity development (Pierrakos et al., 2024). Interactions with experienced professionals offer students access to tacit knowledge and help them navigate the complexities of professional socialization. These aspects were most visible in capstone design as Wake Forest Engineering students worked with many and diverse stakeholders (e.g. faculty mentors, industry mentors, other technical experts, peers, clients, project stakeholders, funders, community partners, etc.) (Pierrakos et a., 2024).

Character development is another area of growth for students who participate in experiential learning. The impact extends to character development and moral reasoning capabilities towards creating more well-rounded professionals. Experiential learning fosters character development by placing students in situations that require ethical decision-making and responsibility (personal and professional). When students engage in real-world projects, they often face authentic ethical dilemmas that require them to apply their values and develop moral reasoning skills. Through collaborative experiential learning activities, students develop important character traits like empathy, collaboration towards respect for diverse perspectives, accountability, courage, humility. Working with peers and community members from different backgrounds helps students understand various viewpoints and develop a sense of social responsibility. The reflective component of experiential learning is particularly crucial for character development. When students reflect on their experiences, they examine not just what they learned academically, but how the experience changed them personally and what values were challenged or reinforced. Experiential learning also builds resilience and perseverance as students navigate complex, open-ended problems. Unlike traditional education with clear right/wrong answers, experiential learning often involves setbacks and failures that students must overcome, helping them develop grit and a growth mindset. Some of our previous publications demonstrate these positive impacts (Pierrakos et al., 2024; Brock et al. 2024; Koehler et al., 2023).

Positive Outcomes of Experiential Learning across the Curriculum

The 100% experiential learning curriculum has yielded significant positive outcomes for Wake Forest Engineering students:

- **Career Preparation:** 95% job placement at graduation
- **Internship Placement:** Over 70% of students participated in industry internships
- **Practical Experiences:** Students could showcase over 15 curricular projects during interviews to secure internships and jobs
- **Professional Skills:** Students highlighted learning gains with communication, team, and leadership skills
- **Character Cultivation:** Students noted character cultivation as a result of experiential learning (e.g. empathy, resilience, courage, humility, purpose, justice, responsibility, etc.)
- **Global Perspective:** Over 50% of students participated in study abroad experiences
- **Research Engagement:** Over 50% of students participated in undergraduate research
- **Interdisciplinary Learning:** Over 75% completed a minor or second major beyond engineering
- **Curricular Flexibility and Customization:** Over 75% of engineering students pursued and engineering concentration (five available to them and optional to them).
- **Diversity:** 40% women and 25% racial and ethnic minorities, making it the most diverse department on campus
- **Academic Recognition:** Wake Forest Engineering became the highest ranked (US News Report) program at the university

These outcomes demonstrate the effectiveness of the experiential learning curriculum in preparing well-rounded engineers while attracting and retaining a diverse student population.

VI. DISCUSSION AND CONCLUSIONS

The Wake Forest Engineering experience offers several key insights into implementing experiential learning across an engineering curriculum:

Theoretical Grounding Is Essential: Faculty can be more effective in implementing experiential learning when they understand the underlying learning and motivational theories, allowing for intentional design rather than surface-level applications. Different pedagogies leverage different motivational mechanisms, and pedagogies with complementary theoretical foundations can be effectively combined.

Pedagogical Diversity Creates Synergy: Rather than relying on a single approach, integrating multiple experiential learning pedagogies creates a richer learning environment that supports different learning styles and develops diverse competencies. Project-Based Learning emerged as the most versatile pedagogy, aligning strongly with almost all learning theories due to its comprehensive nature.

Integration Requires Intentional Design: Successful experiential learning implementation depends on careful curriculum mapping to ensure complementary learning experiences that build from foundational skills to complex applications. This requires significant coordination among faculty and deliberate alignment with program learning outcomes.

Faculty Development Is Critical: Faculty need both support and autonomy to effectively implement experiential learning. Providing theoretical foundations, practical training, and opportunities for collaborative teaching enhances success and innovation.

Character Development Emerges from Well-Designed Experiential Learning: Our recent research (Pierrakos, Yazdani, & Koehler, 2024) demonstrates that student-centered approaches of project-based learning, mastery-based learning, self-directed learning, and flipped classroom learning can simultaneously develop technical competence and character virtues. In our thermal-fluids course, course features like collaborative problem-solving, opportunities to revise work, and structured reflection fostered virtues including resilience, courage, humility, and critical thinking. The explicit connection between pedagogical approach and character development represents an important emerging dimension of experiential learning implementation.

Sustainability and Continuous Improvement

Sustainable implementation of experiential learning requires a carefully orchestrated system of interconnected elements:

Continuous Communication: Regular information sharing through multiple channels maintains engagement and creates a sense of shared purpose.

Comprehensive Faculty Support: Both material resources and developmental support are essential for long-term faculty engagement with experiential pedagogy.

Evidence Gathering: Systematic collection of both quantitative and qualitative data demonstrates program value and guides improvements.

Strategic Partnerships: Structured engagement with industry and community partners ensures a steady flow of authentic projects and career pathways.

Regular Assessment and Adjustment: Systematic review cycles enable responsive adaptation to changing needs and emerging opportunities.

Recognition and Celebration: Acknowledging achievements maintains enthusiasm and commitment to experiential learning.

Knowledge Management: Comprehensive documentation ensures that successful practices persist beyond individual champions.

Institutional Infrastructure: Dedicated support mechanisms provide the foundation for sustained implementation.

Recommendations for Other Institutions

Based on the Wake Forest Engineering experience, we offer the following recommendations for institutions seeking to implement comprehensive experiential learning:

1. **Start with Theory:** Ground experiential learning implementation in established learning and motivational theories to inform design decisions and faculty development.
2. **Build Faculty Capacity Gradually:** Begin with pilot projects and team teaching before expanding to comprehensive implementation.
3. **Create Flexible Infrastructure:** Develop adaptable physical spaces and support systems that can accommodate diverse experiential learning approaches.
4. **Align with Institutional Culture:** Connect experiential learning initiatives to the institution's existing values and strengths to enhance acceptance.
5. **Develop Robust Assessment:** Create assessment approaches that capture both technical competencies and professional capabilities.
6. **Cultivate External Partnerships:** Establish relationships with industry and community partners who can provide authentic contexts for student learning.
7. **Document and Share Successes:** Create mechanisms for capturing and disseminating effective practices within and beyond the institution.
8. **Integrate Character Development with Technical Learning:** Consider how experiential learning implementations can intentionally cultivate virtues like resilience, courage, and humility alongside technical skills.

Conclusion and Future Directions

The Wake Forest Engineering experience demonstrates that comprehensive implementation of experiential learning across an engineering curriculum is not only possible but highly effective in preparing graduates with both technical competence and professional capabilities. The program's success in attracting and retaining a diverse student population while achieving excellent outcomes suggests that this approach may help address persistent challenges in engineering education. Future research should examine the long-term career trajectories of graduates from experiential learning-focused programs, investigate optimal combinations of experiential learning pedagogies for different learning outcomes, and explore how experiential approaches might be scaled to larger engineering programs with different resource constraints. By sharing this model of 100% experiential learning implementation, we hope to inspire other engineering programs to transform their curricula and educational approaches, ultimately preparing more diverse, capable, and well-rounded engineers ready to address society's complex challenges.

ACKNOWLEDGEMENTS

The author would like to acknowledge the Wake Forest Engineering faculty, staff, students, and the many colleagues across the university who supported the launch and development of the new engineering department and the Wake Forest Engineering curriculum. The author would like to thank the National Science Foundation for funding and mentoring her as an NSF-funded investigator and Program Director (2015-2017 and 2024-now). NSF made visible to me what is possible in terms of transformation in engineering education and higher education. I am also grateful for everything I learned at the National Science Foundation (NSF) about ethics, bias, and conflict of interest. I am indebted to what NSF has enabled me to learn as an educator, researcher, and academic leader. Engineering education and higher education must transform, and transformation is possible. The author would like to acknowledge the collaborative partnership with the Kern Entrepreneurial Engineering Network (KEEN) of the Kern Family Foundation for the welcoming of Wake Forest Engineering as a KEEN partner institution in 2018. KEEN has served as a most essential partner to supporting faculty development within WFU Engineering in ways that WFU faculty development efforts could not support. This work has been funded by the National Science Foundation (as part of an IPA agreement) and supported by a KEEN award titled "Educating the Whole Engineer through Character and Entrepreneurial Mindset." The views presented in this paper are those of the author and do not reflect the views of the National Science Foundation or KEEN. Lastly, the author would like to disclose the use of AI (Claude used in April 2025) for the synthesis of her archival documents to produce tables and some content that was edited before final dissemination.

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