

Innovative Reconstruction and Practical Pathways of AI-Empowered Curriculum System for Electrical Engineering and Automation Major

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Abstract: The rapid development of artificial intelligence (AI) technology has brought unprecedented opportunities and challenges to electrical engineering and automation education. This paper explores the innovative reconstruction of curriculum systems in electrical engineering and automation majors through AI empowerment, examining theoretical frameworks, practical implementation pathways, and educational outcomes. By analyzing current educational practices and emerging trends, this study proposes a comprehensive approach to integrating AI technologies into traditional electrical engineering curricula while maintaining disciplinary foundations. The research emphasizes the importance of interdisciplinary integration, practical skill development, and adaptive learning methodologies in preparing students for Industry 4.0 demands.

Keywords: Artificial Intelligence, Curriculum, Electrical Engineering and Automation Major

1. Introduction

The electrical engineering and automation discipline stands at a critical juncture where traditional engineering education must evolve to meet the demands of an increasingly AI-driven industrial landscape. As manufacturing processes become more intelligent and automated, educational institutions face the imperative to restructure their curriculum systems to adequately prepare students for future professional challenges [2]. The integration of AI technologies into electrical engineering education is not merely about adding new courses but requires a fundamental rethinking of pedagogical approaches, learning outcomes, and skill development strategies.

Recent developments in generative AI and machine learning have demonstrated significant potential in transforming STEM education, offering new possibilities for personalized learning, enhanced problem-solving capabilities, and improved student engagement [1]. For electrical engineering and automation majors, this transformation is particularly relevant as the field increasingly relies on intelligent systems, data-driven decision-making, and automated control mechanisms. However, the integration of AI into existing curriculum frameworks presents numerous challenges, including the need to balance theoretical foundations with practical applications, address faculty training requirements, and ensure that students develop both technical competencies and essential soft skills [9].

This paper examines how AI empowerment can drive innovative reconstruction of curriculum systems in electrical engineering and automation education. By drawing on recent research and practical implementations across various engineering disciplines, we propose a comprehensive framework that addresses curriculum design, teaching methodologies, assessment strategies, and industry-education integration. The goal is to create an educational model that not only incorporates AI technologies but also cultivates students' ability to innovate, adapt, and lead in an AI-native engineering environment [7].

2. Current State of AI Integration in Engineering Education

The landscape of engineering education has witnessed substantial transformation with the advent of AI technologies. Research indicates that AI applications in higher engineering education have expanded across multiple dimensions, including intelligent tutoring systems, automated assessment tools, personalized learning platforms, and virtual laboratory environments [10]. These technologies have demonstrated capacity to enhance learning outcomes, increase student engagement, and provide more

efficient educational delivery mechanisms. In the context of manufacturing and industrial engineering education, AI integration has become particularly critical. Studies examining manufacturing process education for Industry 4.0 reveal that multi-case study approaches incorporating AI-driven simulations and digital twin technologies significantly improve students' understanding of complex production systems [2]. These implementations demonstrate that AI can bridge the gap between theoretical knowledge and practical industrial applications, providing students with realistic problem-solving experiences that were previously difficult to replicate in educational settings.

However, current implementations also reveal significant gaps and challenges. A comprehensive review of AI applications in higher engineering education identifies several persistent issues, including inadequate faculty preparation, limited institutional resources, concerns about academic integrity, and insufficient attention to ethical considerations [10]. Furthermore, curriculum integration often remains superficial, with AI technologies added as supplementary tools rather than being fundamentally embedded into pedagogical frameworks. This approach fails to leverage the full transformative potential of AI in reshaping how students learn, think, and solve engineering problems. The situation is particularly acute in regions where educational systems are still adapting to rapid technological changes. Research on civil engineering education in Latin America, for instance, highlights a significant curriculum gap regarding both AI integration and soft skills development, with global implications for engineering workforce preparation [9]. These findings underscore the need for comprehensive, systematic approaches to curriculum reconstruction that address not only technological integration but also broader educational objectives including critical thinking, creativity, and interdisciplinary collaboration.

3. Theoretical Framework for AI-Empowered Curriculum Reconstruction

Developing an effective framework for AI-empowered curriculum reconstruction in electrical engineering and automation requires consideration of multiple theoretical perspectives. The AI-native education framework proposed for mechanical engineering provides valuable insights that can be adapted to electrical engineering contexts [7]. This framework emphasizes the need to move beyond traditional course-based structures toward integrated learning experiences that reflect the interconnected nature of modern engineering practice. Central to this theoretical approach is the concept of interdisciplinary integration. Research on smart construction professional curriculum clusters demonstrates that breaking down traditional disciplinary boundaries and creating interconnected course systems can significantly enhance students' ability to address complex, real-world problems [12]. For electrical engineering and automation, this means integrating knowledge from computer science, data analytics, control theory, and industrial systems into cohesive learning pathways rather than treating them as separate domains.

The framework must also address the dual challenge of maintaining rigorous technical foundations while developing adaptive, future-oriented competencies. Studies on chemical process control education illustrate how AI assistance can be integrated into traditional engineering courses without compromising fundamental principles [13]. This approach suggests that AI should serve as an enhancement tool that deepens understanding rather than a replacement for core engineering knowledge. Students must develop strong foundational skills in circuit analysis, control systems, power electronics, and automation principles while simultaneously learning to leverage AI tools for optimization, prediction, and decision support. Another critical theoretical consideration involves the development of AI literacy as a distinct competency domain. Research examining AI literacy pathways in technology education emphasizes the importance of structured, progressive learning experiences that build from basic awareness to advanced application capabilities [14]. For electrical engineering students, AI literacy encompasses understanding machine learning algorithms, data preprocessing techniques, model training and validation, and the ability to critically evaluate AI system performance in engineering contexts. This literacy must be developed systematically across the curriculum rather than concentrated in isolated courses.

The theoretical framework must also incorporate principles of sustainable development and ethical considerations. Studies on harnessing generative AI for education emphasize the importance of preparing students not only for technical proficiency but also for responsible innovation that considers social, environmental, and ethical implications [8]. In electrical engineering and automation, this translates to curriculum components addressing energy efficiency, sustainable manufacturing practices, ethical AI deployment, and the societal impacts of automation technologies.

4. Practical Implementation Pathways

Implementing AI-empowered curriculum reconstruction requires concrete strategies that address course design, teaching methodologies, and learning assessment. Research on the "four-in-one" teaching reform for AI-integrated courses provides a valuable model that combines theoretical instruction, practical experimentation, project-based learning, and industry collaboration [16]. This multifaceted approach ensures that students develop comprehensive competencies rather than fragmented knowledge. At the course level, integration strategies must be carefully designed to align with specific learning objectives. Studies examining mechanical drawing courses in vocational colleges demonstrate how generative AI can transform traditional technical courses by providing intelligent design assistance, automated error detection, and personalized feedback mechanisms [11][17]. For electrical engineering curricula, similar approaches can be applied to courses in circuit design, power system analysis, and control system implementation. AI tools can assist students in design optimization, simulation analysis, and troubleshooting while simultaneously teaching them to understand the underlying principles and limitations of these technologies.

The development of specialized AI-integrated courses represents another important implementation pathway. Research on open-source AI model localization deployment training systems illustrates how industry-education integration can create practical learning experiences that directly address workforce needs [4]. For electrical engineering programs, this might involve courses focused on AI applications in predictive maintenance, intelligent grid management, or automated quality control systems. These courses should emphasize hands-on experience with real datasets, industrial-grade software tools, and authentic problem scenarios. Laboratory and experimental components require particular attention in AI-empowered curricula. Studies on environmental engineering microbiology courses demonstrate how AI-driven teaching models can enhance experimental learning through intelligent data analysis, pattern recognition, and hypothesis testing support [15]. In electrical engineering laboratories, AI integration can enable more sophisticated experiments, real-time data analysis, and virtual extensions of physical equipment. Students can work with digital twins of electrical systems, conduct parametric studies that would be impractical with physical equipment alone, and develop skills in data-driven system optimization.

Assessment methodologies must evolve to reflect the changed learning environment. Research on gamification interventions in AI-focused education reveals that innovative assessment approaches can significantly enhance student engagement and learning outcomes [6]. For electrical engineering courses, this might include project-based assessments where students design and implement AI-enhanced control systems, competitive challenges involving system optimization, and portfolio-based evaluations that document progressive skill development. Assessment should evaluate not only technical correctness but also creativity, problem-solving approaches, and the ability to critically evaluate AI tool outputs.

5. Interdisciplinary Integration and Industry Collaboration

The reconstruction of electrical engineering curricula must extend beyond departmental boundaries to embrace genuine interdisciplinary integration. Research on integrating legal knowledge into AI-driven smart manufacturing curricula demonstrates the value of incorporating perspectives from non-technical disciplines [3]. For electrical engineering students, understanding regulatory frameworks, intellectual property considerations, and legal implications of automated systems is increasingly essential for professional practice. Industry collaboration represents a critical component of effective curriculum reconstruction. Studies examining the construction of training systems under industry-education integration backgrounds emphasize the importance of aligning educational objectives with actual workforce requirements [4]. This alignment can be achieved through multiple mechanisms including industry advisory boards, cooperative education programs, sponsored capstone projects, and joint research initiatives. Such collaborations ensure that curriculum content remains current with technological developments and that students gain exposure to authentic engineering challenges.

The integration of soft skills development within technical curricula deserves particular emphasis. Research highlighting curriculum gaps in civil engineering education points to the critical importance of communication, teamwork, ethical reasoning, and adaptability alongside technical competencies [9]. For electrical engineering programs, this means deliberately designing learning experiences that require collaboration, presentation of technical findings, ethical decision-making, and adaptation to changing project requirements. AI tools can actually facilitate some aspects of soft skills development, for example through collaborative design platforms, automated feedback on technical writing, and simulation

scenarios requiring ethical judgments. Cross-disciplinary project experiences provide particularly valuable learning opportunities. Studies on comprehensive analytical chemistry experiments, while focused on a different discipline, illustrate how complex, multi-faceted projects can integrate diverse knowledge domains and skill sets. In electrical engineering contexts, capstone projects might require students to integrate electrical system design with mechanical components, software development, data analytics, and business considerations. Such projects prepare students for the inherently interdisciplinary nature of modern engineering practice.

6. Challenges and Solutions

Despite the significant potential of AI-empowered curriculum reconstruction, numerous challenges must be addressed for successful implementation. Faculty development represents perhaps the most critical challenge. Many engineering faculty members lack extensive experience with AI technologies and may feel uncertain about how to effectively integrate these tools into their teaching [10]. Solutions include providing structured professional development programs, creating communities of practice where faculty can share experiences and resources, and recognizing pedagogical innovation in promotion and tenure decisions. Resource constraints pose another significant challenge, particularly for institutions with limited budgets. AI technologies often require substantial computational resources, software licenses, and infrastructure investments. However, research on open-source AI model deployment demonstrates that cost-effective solutions exist [4]. Institutions can leverage cloud computing platforms, open-source software tools, and collaborative arrangements with industry partners to provide students with access to necessary technologies without prohibitive costs.

Concerns about academic integrity and appropriate AI use require careful attention. As generative AI tools become more sophisticated, distinguishing between legitimate learning support and inappropriate assistance becomes increasingly complex. Clear policies, explicit learning objectives that emphasize understanding over mere task completion, and assessment designs that require demonstration of genuine comprehension can help address these concerns [1]. Additionally, teaching students about responsible AI use, including proper attribution and awareness of tool limitations, should be integrated throughout the curriculum. Balancing breadth and depth in curriculum design presents an ongoing challenge. The addition of AI-related content must not come at the expense of fundamental electrical engineering principles. Research on post-lithium battery courses illustrates how AI can be integrated to enhance rather than replace core content [5]. The key is identifying opportunities where AI tools can deepen understanding, extend capabilities, or provide new perspectives on traditional topics rather than simply adding more material to already crowded curricula.

7. Future Directions and Recommendations

Looking forward, several key directions emerge for the continued development of AI-empowered electrical engineering education. First, curriculum systems must remain adaptive and responsive to rapid technological change. This requires establishing mechanisms for regular curriculum review, maintaining strong connections with industry partners, and fostering a culture of continuous improvement among faculty and administrators [7]. Second, research on educational outcomes and effectiveness must be prioritized. While many institutions are experimenting with AI integration, systematic evaluation of learning outcomes, skill development, and long-term career impacts remains limited. Rigorous research examining what works, for whom, and under what conditions will be essential for evidence-based curriculum development [10]. Third, attention to equity and access must be maintained. As AI technologies become more central to engineering education, ensuring that all students regardless of background have opportunities to develop relevant competencies becomes increasingly important. This includes addressing digital divides, providing support for students with varying levels of prior preparation, and creating inclusive learning environments where diverse perspectives are valued [8]. Fourth, international collaboration and knowledge sharing should be expanded. Engineering education challenges and opportunities transcend national boundaries, and much can be learned from comparative studies and collaborative initiatives [9]. Developing international standards for AI literacy in engineering, sharing curriculum resources, and facilitating student and faculty exchanges can accelerate progress globally. Finally, the ethical dimensions of AI in engineering practice must receive sustained attention throughout curricula. As electrical engineers increasingly design and implement AI-enabled systems, they must be prepared to consider implications for privacy, fairness, transparency, accountability, and societal impact. Integrating ethical reasoning throughout technical courses, rather than isolating it in

separate ethics courses, can help students develop the habits of mind necessary for responsible professional practice [8].

8. Discussion

The transformation of electrical engineering and automation education through AI empowerment raises important questions about the future nature of engineering expertise and professional identity. As AI systems become increasingly capable of performing routine design calculations, optimization tasks, and even certain aspects of creative problem-solving, the role of human engineers must necessarily evolve. This evolution suggests that educational programs should place greater emphasis on developing uniquely human capabilities that complement rather than compete with AI systems. These include strategic thinking, contextual judgment, ethical reasoning, and the ability to frame problems in ways that leverage both human insight and computational power. The implementation of AI-empowered curricula also highlights tensions between standardization and customization in engineering education. While AI technologies enable unprecedented levels of personalized learning, adapting content and pacing to individual student needs, there remains value in shared learning experiences that build professional community and common knowledge bases. Finding the appropriate balance requires thoughtful consideration of which learning objectives benefit from individualization and which require collective engagement. Moreover, as AI tools provide increasingly sophisticated assistance, educators must carefully consider what constitutes appropriate support versus dependency that undermines genuine learning. The discussion of AI integration in electrical engineering education cannot be separated from broader questions about technological determinism and human agency. While this paper has focused primarily on adapting education to meet the demands of an AI-driven industrial landscape, it is equally important to prepare students to shape that landscape according to human values and societal needs. This requires cultivating critical perspectives on technology, encouraging students to question assumptions about technological inevitability, and empowering them to envision and create alternative futures. Engineering education must produce not only technically competent practitioners but also thoughtful leaders who can guide technological development in socially responsible directions.

9. Conclusion

The innovative reconstruction of curriculum systems in electrical engineering and automation through AI empowerment represents both a significant challenge and an extraordinary opportunity. This paper has examined theoretical frameworks, practical implementation pathways, and critical considerations for successfully integrating AI technologies into engineering education. The evidence suggests that effective integration requires comprehensive approaches that address course design, teaching methodologies, assessment strategies, faculty development, and industry collaboration. Key findings indicate that AI should be integrated as an enhancement to rather than replacement for fundamental engineering education. Students must develop strong foundations in electrical engineering principles while simultaneously building AI literacy and learning to leverage intelligent tools effectively. Interdisciplinary integration, practical skill development, and attention to ethical considerations are essential components of reconstructed curricula. Successful implementation requires addressing significant challenges including faculty preparation, resource constraints, academic integrity concerns, and curriculum balance. However, emerging practices and research findings provide valuable guidance for overcoming these obstacles. As electrical engineering and automation continue to evolve in response to Industry 4.0 demands, educational institutions must remain adaptive, evidence-based, and committed to preparing students for professional success in an AI-driven world. The path forward requires sustained commitment from educators, administrators, industry partners, and policymakers. By embracing innovative approaches while maintaining rigorous standards, electrical engineering education can successfully navigate this transformation and continue to prepare graduates who are technically proficient, ethically grounded, and ready to lead in creating the intelligent systems that will shape our future.

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