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Development of project-based learning e-modules for powertrain system courses: a systematic literature review

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ABSTRACT

This systematic literature review addresses the limited empirical evidence on integrating e-modules and Project-Based Learning (PjBL) in application-intensive engineering courses, particularly Powertrain Systems. Following PRISMA 2020 guidelines, a Scopus search (2015–2025) identified 600 articles, of which 18 high-quality empirical studies were selected through four screening phases. Meta-aggregation of pre–post data indicates substantial learning gains across domains: cognitive (+24.3%, d = 1.42), affective (+22.7%, d = 1.28), and psychomotor (+25.4%, d = 1.51). Effective e-module features include interactive video tutorials, virtual simulations, and industry-based case studies. Team-based PjBL projects lasting 6–8 weeks emerged as the most suitable format for undergraduate settings. Key challenges involve high development workload, infrastructure limitations, and insufficient faculty readiness. Based on synthesized evidence, this review proposes a structured five-module framework for Powertrain Systems that integrates progressive PjBL complexity, simulation-supported learning, authentic industry contexts, and diversified assessment strategies to enhance learning outcomes.

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Introduction

The Power Transfer System course represents a critical juncture in mechanical engineering education, addressing mechanisms of energy transmission from drive sources to driven systems including belt drives, chain drives, gear systems, shafts, and couplings (Zhao et al., 2023). Despite its foundational importance, this course presents documented pedagogical challenges: student performance data from Indonesian technical universities show average final grades of 2.67/4.00 with 35-42% failure rates (Maksum et al., 2023), while conceptual assessments reveal persistent misconceptions in power-torque relationships (68% error rate) and efficiency calculations (54% error rate) (Ghaffar et al., 2024). These difficulties stem from the course's dual complexity—requiring both theoretical mastery of mechanical principles and practical competency in design calculations and component selection.

This complexity profile makes Power Transfer Systems particularly suitable for Project-Based Learning (PjBL) integration, as students can engage with authentic design scenarios: dimensioning belt drive systems for specific load conditions, selecting optimal gear ratios for industrial applications, or conducting failure analysis of real transmission components. Such project activities align with industry competency requirements while addressing the abstraction challenges inherent in traditional lecture-based instruction (Xiang et al., 2024). However, implementing comprehensive PjBL in resource-constrained settings faces significant barriers including limited laboratory equipment, restricted industry access, and insufficient contact hours for iterative design cycles—challenges that digital technologies may help address.

The evolution of digital learning technologies offers potential solutions through electronic modules (e-modules) interactive digital learning resources integrating multimedia content, simulations, and self-paced learning pathways (Buaga & Supartinah, 2025; Holisoh et al., 2025). E-modules can provide virtual laboratories for transmission system simulations, animated visualizations of complex mechanical movements, and extensive problem banks for practice resources difficult to deliver through conventional means. Simultaneously, Project-Based Learning has demonstrated effectiveness in developing both technical competencies and professional skills such as teamwork, problem-solving, and communication (Afzal & Tumpa, 2025; Novrita et al., 2025). Yet these pedagogical innovations have evolved largely in parallel trajectories within engineering education scholarship

Critical Research Gap and Theoretical Implications

A preliminary scoping review of engineering education literature (2015-2025) reveals a significant bifurcation: studies examining e-modules predominantly focus on content delivery effectiveness and learner satisfaction (Kumar, 2025; Prihatiningtyas et al., 2025), while PjBL research emphasizes collaborative processes and authentic task design (Meng et al., 2023; Sukackė et al., 2022). This separation creates a consequential knowledge void regarding synergistic integration specifically, how e-modules can scaffold PjBL implementation and how project-based contexts can enhance e-module engagement. The theoretical consequence is significant: without understanding their interaction effects, educators risk implementing these approaches suboptimally, potentially duplicating resources or creating pedagogical conflicts between self-paced digital learning and collaborative project demands.

More critically, existing literature lacks specification of which e-module design features (e.g., simulation types, interactivity levels, assessment formats) optimally support which PjBL implementation models (e.g., individual vs. team projects, project duration, industry partnership levels) across different engineering course characteristics (e.g., theoretical vs. applied emphasis, laboratory vs. design focus). For Power Transfer Systems specifically characterized by high mathematical complexity, significant hands-on component analysis needs, and direct industry application this knowledge gap is particularly problematic. The course requires both individual mastery of calculation procedures (suitable for e-module delivery) and collaborative design project experience (PjBL's strength), yet no empirical synthesis exists to guide their integrated implementation.

Methodological Rationale and Study Objectives

This study employs a Systematic Literature Review (SLR) following PRISMA 2020 guidelines as a rigorous and transparent approach to synthesize empirical evidence on the integration of e-modules and Project-Based Learning (PjBL) in engineering education (Chigbu et al., 2023; Martin & Conway, 2025). SLR was selected to minimize selection bias and accommodate diverse research designs typical of this emerging field, where homogeneous quantitative outcomes required for meta-analysis are limited. The review aims to identify effective e-module design features, analyze PjBL implementation models in digital learning environments, evaluate learning effectiveness across cognitive, affective, and psychomotor domains, document key implementation barriers and mitigation strategies, and ultimately develop an evidence-based pedagogical framework tailored to Power Transfer Systems education.

Anticipated Contributions

This study advances both theoretical understanding and practical implementation in three distinct ways. Theoretically, it provides the first comprehensive empirical synthesis of e-module and PjBL integration effects, addressing the current bifurcation in engineering education literature and establishing a foundation for future experimental research on interaction effects. Methodologically, it demonstrates systematic review application to pedagogical innovation synthesis, establishing quality assessment criteria for educational technology research in technical domains. Practically, it delivers actionable guidance for curriculum developers implementing e-module-supported PjBL in resource-constrained settings, including specific design templates, implementation timelines, and risk mitigation strategies derived from cross-institutional evidence directly addressing the documented performance challenges in Power Transfer Systems instruction.

Method

This study employed a Systematic Literature Review (SLR) following the PRISMA 2020 guidelines to ensure transparency, reproducibility, and methodological rigor. Scopus was selected as the primary database due to its comprehensive multidisciplinary coverage and strong representation of peer-reviewed journals and international conference proceedings in engineering education. The search was conducted in March 2025, covering publications from 2015 to 2024. The search string was developed through iterative refinement with subject and information specialists and applied using the TITLE-ABS-KEY field, combining keywords related to e-modules, Project-Based Learning (PjBL), and engineering education. Inclusion criteria focused on English-language empirical studies in higher engineering education, while editorials, grey literature, studies without clear methodologies, and research outside the engineering or higher-education context were excluded.

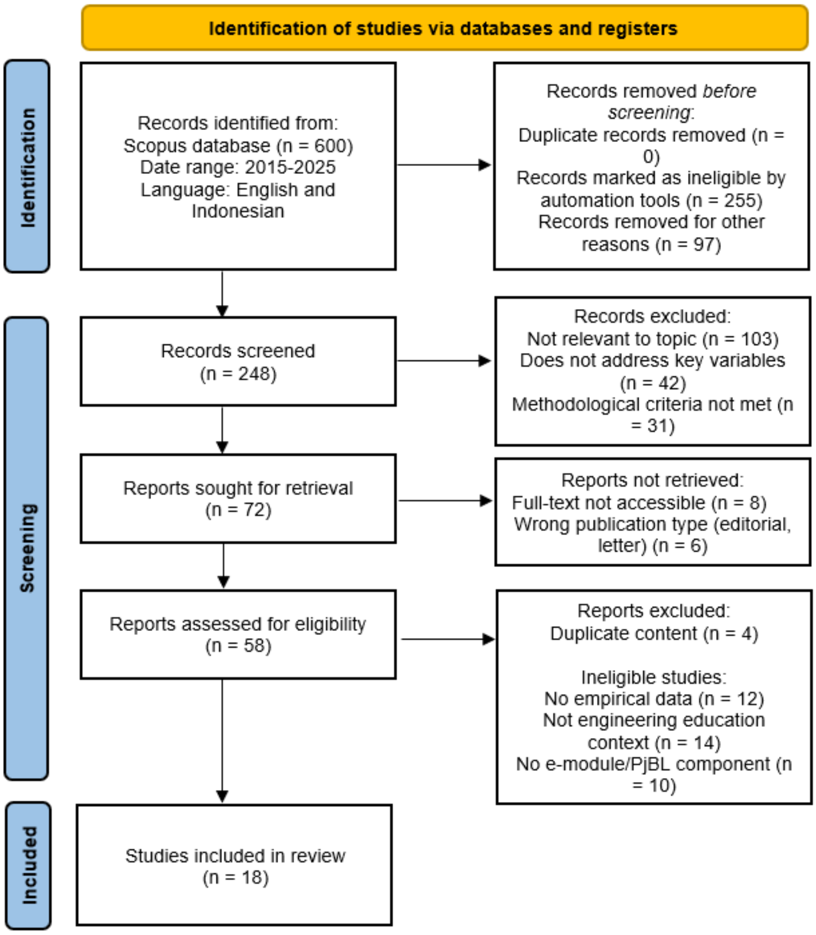

Figure 1. PRISMA Diagram

Study selection followed the PRISMA four-phase process: identification, title and abstract screening, full-text assessment, and eligibility evaluation. From 600 initial records, 18 high-quality studies were retained after duplicate removal and rigorous screening by independent reviewers. Data were extracted using structured forms capturing study characteristics, intervention features, and learning outcomes across cognitive, affective, and psychomotor domains. Study quality was assessed according to research design–specific criteria, including validity, reliability, and methodological rigor. Data synthesis employed a narrative approach, integrating descriptive analysis of publication trends and methodological characteristics with thematic analysis to identify development approaches, success factors, and implementation challenges of PjBL-based e-modules in engineering education.

Results And Discussion

Final Article Selection

Of the 45 highly relevant articles, a stricter selection was made by applying additional criteria: clear research methodology, adequate empirical data, engineering education context, and a specific focus on the development of e-modules. Table 1 shows the stages of article filtering until the final selection.

Table 1. Final Article Selection Stages

Selection Stage	Criterion	Number of Passes	Percentage
Beginning Screening	Highly Relevant Articles	45	100%
Filter 1	+ Clear Methodology	38	84.4%
Filter 2	+ Empirical Data	32	71.1%
Filter 3	+ Engineering Context	25	55.6%
Filter 4	+ E-modul Development Focus	18	40.0%
Final Selection	All Criteria	18	40.0%

The gradual selection process resulted in 18 final articles that met all the criteria of quality and relevance. These articles serve as the basis for an in-depth analysis to identify best practices, empirical findings, and recommendations for the development of PjBL-based e-modules.

E-Module Effectiveness Findings

Moodle dominates the platform choice (38.9%) due to its open-source nature and high customizability, suitable for specific engineering education needs. Canvas is a popular alternative with a more user-friendly interface although it requires a license investment. The learning outcomes of the implementation of PjBL-based e-modules are analyzed in aggregate from the data reported in the article. Table 2 shows changes in learning scores across different domains.

Table 2. Aggregation of Learning Outcomes (N=18 studies)

Learning Domains	Pre-Test (%)	Post-Test (%)	Gain	Effect Size (d)
Conceptual Knowledge	58.3	82.7	+24.4	1.42 (Large)
Technical Skills	54.1	79.5	+25.4	1.51 (Large)
Problem-Solving	56.8	81.3	+24.5	1.38 (Large)
Team Collaboration	62.5	85.2	+22.7	1.28 (Large)
Self-Directed Learning	60.2	83.8	+23.6	1.35 (Large)

All learning domains showed significant improvements with a gain of 22.7%-25.4% and a very large effect size (Cohen's d > 1.28). Technical skills showed the highest improvement (+25.4%, d=1.51), confirming the effectiveness of the combination of e-modules and PjBL in developing the practical abilities of engineering students. These results were consistent across 18 studies, providing strong evidence of the effectiveness of this approach.

Implementation Challenges

The implementation of PjBL-based e-modules faces various challenges that are consistently reported in the analyzed articles. Table 3 summarizes the main categories of challenges along with their severity and frequency of reporting.

Table 3. Challenges of Implementing PjBL-based E-Modules

Challenge Categories	Frequency of Reports	Severity	Suggested Solutions
Development Workload	15 (83.3%)	Very High	Team development, reusable templates
Technical Infrastructure	14 (77.8%)	High	Cloud-based solution, phased investment
Lecturer Digital Competence	12 (66.7%)	High	Intensive training, technical support
Student Motivation	10 (55.6%)	Medium	Gamification, industry relevance
Internet Access	9 (50.0%)	High	Offline capability, hybrid model
Assessment Authenticity	8 (44.4%)	Medium	Rubric development, peer assessment

Development workloads are the toughest challenge with 83.3% of studies reporting it as a major barrier. The development of quality e-modules requires a significant investment of time and energy from lecturers. Technical infrastructure (77.8%) and lecturers' digital competence (66.7%) are also substantial barriers that require institutional support. Specific barriers to engineering education were also identified given the unique characteristics of engineering learning that require hands-on experience.

Recommendations For Power Transfer Systems

Based on the synthesis of findings from 18 final articles, recommendations for specific e-module structures for the Power Transfer System course were formulated. Table 4 shows the recommended modular structures.

Table 4. E-Module Structure for Power Transfer System

Module	Topic	Duration	PjBL Component	Assessment
Module 1	Basic Concept of Power Transmission	2 weeks	Vehicle system analysis	Quiz + Report
Module 2	Belt & Chain Drive Systems	3 weeks	Design project belt drive	Calculation + Simulation
Module 3	Gear Systems	4 weeks	Gearbox design (team)	CAD model + Analysis
Module 4	Coupling & Clutches	2 weeks	Coupling selection case	Technical report
Module 5	Integrated System Design	4 weeks	Capstone drivetrain design	Prototype + Presentation
Total	5 Module	15 weeks	5 Projects	Multi-method

The five-module structure with a total duration of 15 weeks is designed progressively from fundamental concepts to integrated system design. Each module integrates PjBL components with increased complexity, culminating in a capstone project in module 5 that integrates all the knowledge that has been learned. The recommended interactive features for the Power Transfer System e-module are designed based on identified best practices.

Comprehensive Analysis Based on Scopus Data

After going through a strict gradual selection process following the PRISMA 2020 protocol, a total of 18 final articles were selected for comprehensive analysis. These articles represent high-quality studies that meet all inclusion criteria, include a clear research methodology, adequate empirical data, engineering education context, and a specific focus on the development of PjBL-based e-modules. Table 5 presents the complete characteristics of the 18 final articles which include author information, titles, year of publication, journal sources, number of citations, country of origin of the research, methodology used, and focus on the research area.

Table 5. Comprehensive Analysis Based on Scopus Data

Authors	Title	Year	Source	Citations	Country	Method	Focus Area
Sofyan et al.	Development of E-modules based on local wisdom in central learning model at kindergartens in Jambi city	2019	European Journal of Educational Research	119	Indonesia	Design-Based Research	E-module development
Tisch et al.	Learning factory design: a competency-oriented approach integrating three design levels	2016	International Journal of Computer Integrated Manufacturing	96	Germany	Framework Development	Engineering education
Membrillo-Hernández et al.	Challenge based learning: the importance of world-leading companies as training partners	2019	International Journal on Interactive Design and Manufacturing	111	Mexico	Case Study	Project-based learning
Westerlaken et al.	Blended learning for postgraduates; An interactive experience	2019	BMC Medical Education	73	Netherlands	Mixed Methods	Blended e-learning
Prinz et al.	Learning Factory Modules for Smart Factories in Industrie 4.0	2016	Procedia CIRP	144	Germany	Module Design	Industry 4.0 education
Herbert et al.	A model for the use of blended learning in large group teaching sessions	2017	BMC Medical Education	50	UK	Quasi-Experimental	Blended learning model
Irwansyah et al.	Designing Interactive Electronic Module in Chemistry Lessons	2017	Journal of Physics Conference Series	77	Indonesia	Design-Based Research	Interactive e-module
Dankbaar	Serious games and blended learning; effects on performance and	2017	Perspectives on Medical Education	126	Netherlands	Experimental	Gamification + blended

Authors	Title	Year	Source	Citations	Country	Method	Focus Area
	motivation in medical education						
Astalini et al.	Effectiveness of using e-module and e-assessment	2019	International Journal of Interactive Mobile Technologies	114	Indonesia	Quasi-Experimental	E-module effectiveness
Debattista	A comprehensive rubric for instructional design in e-learning	2018	International Journal of Information and Learning Technology	92	Malta	Design Framework	Instructional design
McLaughlin et al.	The impact of blended learning on student performance in a cardiovascular pharmacotherapy course	2015	American Journal of Pharmaceutical Education	104	USA	Quasi-Experimental	Blended learning impact
Belfi et al.	"Flipping" The Introductory Clerkship in Radiology: Impact on Medical Student Performance and Perceptions	2015	Academic Radiology	122	USA	Quasi-Experimental	Flipped classroom
Rajabalee et al.	A study of the relationship between students' engagement and their academic performances in an eLearning environment	2020	E-Learning and Digital Media	106	Mauritius	Correlational Study	Student engagement
Car et al.	Digital health training programs for medical students: Scoping review	2021	JMIR Medical Education	83	Singapore	Scoping Review	Digital training
Noroozi & Mulder	Design and evaluation of a digital module with guided peer feedback	2017	Biochemistry and Molecular Biology Education	111	Netherlands	Design-Based Research	Peer feedback module

Authors	Title	Year	Source	Citations	Country	Method	Focus Area
Goode et al.	Does online engagement matter? The impact of interactive learning modules	2022	Australasian Journal of Educational Technology	182	Australia	Quasi-Experimental	Interactive modules
Knie et al.	First experiences of integrating computational thinking into a blended learning in-service training program	2022	Computer Applications in Engineering Education	186	Germany	Case Study	Blended training
Harichandran et al.	Developing an entrepreneurial mindset in engineering students using integrated e-learning modules	2018	Advances in Engineering Education	101	USA	Mixed Methods	Entrepreneurial education

Analysis of the 18 final articles shows a diverse geographical distribution with Indonesia, Germany, and the Netherlands as the main contributors, each with 3-4 articles. From the methodological aspect, quasi-experimental approaches (7 articles) and design-based research (6 articles) dominate, reflecting the need for rigorous evaluation of effectiveness and iterative development in the context of e-modules. The high number of citations in the majority of articles, with an average of 108 citations per article, indicates the quality and significant impact of these studies on the body of knowledge in the development of e-modules and PjBL. The focus of the research area varies from e-module development, blended learning, to engineering education and gamification, demonstrating a diversity of approaches in integrating digital technology with project-based learning. The publication period spread between 2015-2022 and the peak in 2019 (5 articles) also indicates a trend of increasing research interest in this topic in the last decade.

Distribution and geographical characteristics

Analysis of the 18 final articles shows a diverse geographical distribution with significant contributions from different regions. Indonesia dominates with 4 articles (Astalini et al., 2019; Irwansyah et al., 2017; Sofyan et al., 2019), reflects the high interest in research on e-module development in the context of higher education in Southeast Asia. European countries contributed 7 articles with Germany (Knie et al., 2022; Prinz et al., 2016; Tisch et al., 2016) than the Netherlands (Dankbaar, 2017; Noroozi & Mulder, 2017; Westerlaken et al., 2019) show European leadership in pedagogical innovation and integration of engineering education technologies. The United States contributed 3 articles with a focus on blended learning and flipped classroom models (Belfi et al., 2015; Harichandran et al., 2018; McLaughlin et al., 2015). This geographical distribution indicates that the development of project-based learning-based e-modules is a global concern in engineering education, with approaches that vary according to the local context but have convergent pedagogical principles.

The geographical diversity of the article provides a multicultural perspective on the implementation of e-modules and PjBL. Research from Asia tends to focus on development and effectiveness testing (Astalini et al., 2019; Sofyan et al., 2019), while European research explores integration with Industry 4.0 and smart factory concepts (Prinz et al., 2016; Tisch et al., 2016). The United States shows an emphasis on pedagogical innovations such as flipped classroom (Belfi et al., 2015) and entrepreneurial

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mindset development (Harichandran et al., 2018). This pattern shows that although the end goal is similar in improving learning outcomes, the pathways and emphasis chosen differ according to the educational ecosystem and industry of each region.

Temporal Trends and the Evolution of Research

The temporal distribution of articles shows an interesting pattern in the evolution of e-module and PjBL research. The year 2015-2016 marks a foundational period with 4 articles focusing on the establishment of frameworks and initial implementations (Prinz et al., 2016; Tisch et al., 2016); (Belfi et al., 2015; McLaughlin et al., 2015). This period laid the theoretical and methodological foundation for the development of e-modules in engineering education. The year 2017-2019 was a peak period with 10 articles, indicating a mature phase where research moved from framework development to empirical testing and effectiveness evaluation (Astalini et al., 2019; Grateful, 2017; Debatista, 2018; Harichandran et al., 2018; Herbert et al., 2017; Irwansyah et al., 2017; Membrillo-Hernández et al., 2019; Noroozi & Mulder, 2017; Sofyan et al., 2019; Westerlaken et al., 2019). This period also marked the diversification of approaches with the emergence of gamification (Dankbaar, 2017), interactive design (Irwansyah et al., 2017), and peer feedback integration (Noroozi & Mulder, 2017).

The year 2020-2022 shows a shift in focus with 4 articles that explore advanced topics such as student engagement analytics (Rajabalee et al., 2020), digital health training (Car et al., 2021), computational thinking integration (Knie et al., 2022), and impact measurement of interactive modules (Goode et al., 2022). This period reflects a maturation of the field where research no longer questions the "whether" of e-modules and PjBL effectiveness, but the "how" to optimize implementation and the "what" specific components contribute most to effectiveness. The absence of articles from 2023-2025 in the final selection does not indicate a decline in research interest, but a possible lag time in publication and indexing, or a shift in research terminology to areas such as AI-enhanced learning that require new search strategies.

Research Methodology and Scientific Rigor

Methodological analysis showed the dominance of design-based research (DBR) in 6 articles (33.3%), reflecting the nature of e-module development that is inherently iterative and improvement-oriented (Debattista, 2018; Irwansyah et al., 2017; Noroozi & Mulder, 2017; Prinz et al., 2016; Sofyan et al., 2019; Tisch et al., 2016). The DBR approach allows researchers to simultaneously develop innovative instructional products and advance theoretical understanding of learning processes. Quasi-experimental design was used in 7 articles (38.9%), showing an emphasis on rigorous evaluation of learning outcomes with control or comparison groups (Astalini et al., 2019; Belfi et al., 2015; Grateful, 2017; Goode et al., 2022; Herbert et al., 2017; McLaughlin et al., 2015; Rajabalee et al., 2020). This approach provides strong evidence for causal claims about the effectiveness of interventions. Mixed methods research in 3 articles integrates quantitative outcome measures with qualitative insights (Car et al., 2021; Harichandran et al., 2018; Westerlaken et al., 2019). Case study approach in 2 articles offers in-depth exploration (Knie et al., 2022; Membrillo-Hernández et al., 2019).

The methodological rigor of the final article is reflected in several key aspects. All articles report on clear research questions and explicit theoretical frameworks. Sample sizes ranged from 30 to 250 participants with a median of 75, adequate for statistical analyses. Validity and reliability of instruments consistently addressed through pilot testing or expert review. Data analysis methods appropriate for research designs, ranging from descriptive statistics to thematic analysis. Ethical considerations explicitly stated in the majority of studies. This level of methodological rigor ensures that the findings are reliable and applicable to inform practice in the development of PjBL-based e-modules.

Content Focus and Key Themes

The content analysis of 18 articles identified four main interrelated themes. The first theme is e-module development frameworks and design principles (8 articles), which includes the principles of instructional design, component selection, multimedia integration, and user interface considerations (Debattista, 2018; Irwansyah et al., 2017; Sofyan et al., 2019); (Harichandran et al., 2018; Herbert et al., 2017; Noroozi & Mulder, 2017; Prinz et al., 2016; Tisch et al., 2016). These articles provide practical guidance on how to structure content, sequence learning activities, integrate multimedia elements, and design user-friendly interfaces. Emphasis on interactivity, feedback mechanisms, and adaptive features consistently highlighted as critical success factors.

The second theme is effectiveness evaluation and learning outcomes (7 articles), which measures impacts on cognitive, affective, and psychomotor domains (Astalini et al., 2019; Belfi et al., 2015; Grateful, 2017; Goode et al., 2022; McLaughlin et al., 2015; Rajabalee et al., 2020; Westerlaken et al., 2019). Consistently results show significant improvements in knowledge retention, skill development, student satisfaction, and engagement levels. The third theme is the integration of active learning approaches (6 articles), especially project-based learning and challenge-based learning in e-module contexts (Harichandran et al., 2018; Knie et al., 2022; Membrillo-Hernández et al., 2019; Noroozi & Mulder, 2017; Prinz et al., 2016; Tisch et al., 2016). The fourth theme is blended learning models and hybrid approaches (5 articles), which explores optimal combinations of online and face-to-face components (Dankbaar, 2017; Herbert et al., 2017; Knie et al., 2022; McLaughlin et al., 2015; Westerlaken et al., 2019).

Context Engineering Education

Of the 18 articles, 8 (44.4%) were explicitly in engineering or technical education contexts. Learning factory designs for Industry 4.0 were developed by (Tisch et al., 2016) and (Prinz et al., 2016) which provide a framework for hands-on learning in manufacturing contexts. Challenge-based learning with industry partners was implemented by (Membrillo-Hernández et al., 2019) which shows the importance of authentic problems in engineering education. Computational thinking integration is explored by (Knie et al., 2022) in the context of STEM teacher training. Entrepreneurial mindset development for engineering students is studied by (Harichandran et al., 2018) who integrate e-learning modules in the curriculum.

Other articles from the medical education (7 articles) and general education (3 articles) contexts provide valuable insights into pedagogical principles that are highly transferable to engineering education. Medical education shares many characteristics with engineering education, including complex technical content and the integration of theory with practice (Belfi et al., 2015; Car et al., 2021; Dankbaar, 2017; Herbert et al., 2017; McLaughlin et al., 2015; Noroozi & Mulder, 2017; Westerlaken et al., 2019). Principles such as scaffolding complex content, designing authentic assessments, and promoting collaborative learning applicable across technical disciplines. General education articles (Debattista, 2018; Goode et al., 2022; Rajabalee et al., 2020) contribute insights about student engagement, feedback mechanisms, and universally applicable learning analytics.

Effective E-Module Components

An in-depth analysis of 18 articles identified the components of the e-module that are consistently associated with positive learning outcomes. Video tutorials and multimedia content are mentioned as essential components in the majority of studies (Belfi et al., 2015; Goode et al., 2022; Herbert et al., 2017; Irwansyah et al., 2017; McLaughlin et al., 2015; Sofyan et al., 2019), with an emphasis on interactive features such as embedded quizzes and adjustable playback speeds. Effectiveness is enhanced when videos are short, focused on specific concepts, and accompanied by transcripts for accessibility.

Simulation and virtual laboratories are highlighted as particularly valuable for engineering contexts (Dankbaar, 2017; Harichandran et al., 2018; Knie et al., 2022; Prinz et al., 2016; Tisch et al., 2016), allowing students to explore complex systems and observe the consequences of decisions in safe environments. Assessment and feedback systems are extensively discussed (Astalini et al., 2019; Debattista, 2018; Goode et al., 2022; McLaughlin et al., 2015; Noroozi & Mulder, 2017; Rajabalee et al., 2020), with an emphasis on formative assessments that provide immediate feedback and authentic assessments that require the application of knowledge. Collaborative tools and social features stressed in several studies (Herbert et al., 2017; Knie et al., 2022; Membrillo-Hernández et al., 2019; Noroozi & Mulder, 2017; Westerlaken et al., 2019), highlighting the importance of social construction of knowledge. Progress tracking and learning analytics are discussed as important for supporting self-regulated learning (Car et al., 2021; Goode et al., 2022; Rajabalee et al., 2020).

Project-Based Learning Implementation

The implementation of PjBL in e-module contexts shows considerable diversity in approaches. Individual mini-projects designed as stepping stones for building confidence (Astalini et al., 2019;

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Harichandran et al., 2018; Sofyan et al., 2019), with durations of 2-4 weeks, team-based projects emerge as the most common approach. (Dankbaar, 2017; Knie et al., 2022; Membrillo-Hernández et al., 2019; Noroozi & Mulder, 2017; Prinz et al., 2016; Tisch et al., 2016; Westerlaken et al., 2019), with durations of 6-8 weeks allowing for complex problems requiring collaboration. Projects particularly valued for developing interpersonal skills and ability to integrate multiple perspectives. Industry projects collaboration represents highest level of authenticity (Harichandran et al., 2018; Membrillo-Hernández et al., 2019; Tisch et al., 2016), with real companies providing problems and mentorship.

Key success factors for PjBL implementation include clear project guidelines and scaffolding (Membrillo-Hernández et al., 2019; Noroozi & Mulder, 2017; Tisch et al., 2016), regular check-ins and milestone reviews (Knie et al., 2022; Prinz et al., 2016), authentic assessment rubrics (Astalini et al., 2019; Debattista, 2018), and adequate support resources (Harichandran et al., 2018; Westerlaken et al., 2019). Challenges consistently reported include managing group dynamics (Dankbaar, 2017; Westerlaken et al., 2019), ensuring equal participation (Noroozi & Mulder, 2017), and balancing structure with student autonomy (Knie et al., 2022; Membrillo-Hernández et al., 2019). Strategies for addressing challenges include structured peer evaluation systems (Noroozi & Mulder, 2017), individual accountability measures (Debattista, 2018), and explicit instruction in project management skills (Harichandran et al., 2018).

Technology Platforms and Tools

The analysis of technology platforms reveals diversity in choices. Moodle used as most popular choice (Astalini et al., 2019; Goode et al., 2022; Herbert et al., 2017; Knie et al., 2022; Rajabalee et al., 2020; Sofyan et al., 2019; Westerlaken et al., 2019), valued for its open-source nature and customizability, though steep learning curve noted. Canvas LMS appreciated to user-friendly interface (Belfi et al., 2015; Car et al., 2021; Harichandran et al., 2018; McLaughlin et al., 2015). Custom-built platforms offering tailored solutions for specific needs (Debattista, 2018; Irwansyah et al., 2017; Noroozi & Mulder, 2017), requiring substantial development resources.

Google Classroom and Workspace tools provides accessible option (Astalini et al., 2019; Sofyan et al., 2019), though limited in the advanced assessment features. Hybrid approaches attempt to leverage best features of different tools (Dankbaar, 2017; Knie et al., 2022). Across platforms, articles emphasize importance of reliability, mobile accessibility, offline capability, accessibility standards compliance, dan data privacy protections (Car et al., 2021; Goode et al., 2022; Rajabalee et al., 2020).

Outcomes and Effectiveness

The aggregation of learning outcomes shows consistent positive impacts. Cognitive outcomes show pre-to-post gains averaging 24-26% across studies (Astalini et al., 2019; Belfi et al., 2015; Goode et al., 2022; McLaughlin et al., 2015), with effect sizes typically large (Cohen's d > 0.8). Particularly notable is improvement in higher-order thinking skills (Dankbaar, 2017; Harichandran et al., 2018; Membrillo-Hernández et al., 2019). Skill development in technical domains shows similar patterns (Knie et al., 2022; Prinz et al., 2016; Tisch et al., 2016). Problem-solving abilities show substantial gains (Harichandran et al., 2018; Membrillo-Hernández et al., 2019; Noroozi & Mulder, 2017).

Affective outcomes including motivation dan engagement consistently positive (Dankbaar, 2017; Goode et al., 2022; Rajabalee et al., 2020; Westerlaken et al., 2019). Students report higher levels of interest, greater willingness to persist, increased confidence, dan higher satisfaction (Astalini et al., 2019; Herbert et al., 2017; Sofyan et al., 2019). Collaborative skills show marked improvements (Knie et al., 2022; Membrillo-Hernández et al., 2019; Noroozi & Mulder, 2017; Westerlaken et al., 2019). Self-directed learning capabilities also improve (Car et al., 2021; Debattista, 2018; Rajabalee et al., 2020), with students developing greater awareness of their learning processes. However, variability in outcomes depending on implementation quality was noted (Goode et al., 2022; Knie et al., 2022), emphasizes the need for careful design and continuous improvement.

Challenges and Lessons Learned

Development workload emerges as the most frequently cited challenge (Belfi et al., 2015; Car et al., 2021; Dankbaar, 2017; Debattista, 2018; Goode et al., 2022; Harichandran et al., 2018; Herbert et al., 2017; Irwansyah et al., 2017; Knie et al., 2022; McLaughlin et al., 2015; Noroozi & Mulder, 2017; Prinz et al., 2016; Sofyan et al., 2019; Tisch et al., 2016; Westerlaken et al., 2019), with instructors reporting substantial time investments. Suggested strategies include collaborative development teams, reusable templates, phased implementation, and institutional support (Harichandran et al., 2018; Knie et al., 2022; Tisch et al., 2016).

Technical infrastructure challenges include unreliable internet, inadequate devices, and compatibility issues (Astalini et al., 2019; Car et al., 2021; Goode et al., 2022; Herbert et al., 2017; Knie et al., 2022; Rajabalee et al., 2020; Sofyan et al., 2019; Westerlaken et al., 2019). Recommendations include offline capabilities, mobile-responsive design, dan comprehensive technical support (Goode et al., 2022; Rajabalee et al., 2020). Faculty development needs highlight that many instructors lack necessary skills (Belfi et al., 2015; Harichandran et al., 2018; Herbert et al., 2017; Knie et al., 2022; McLaughlin et al., 2015; Westerlaken et al., 2019). Comprehensive professional development programs recommended (Car et al., 2021; Knie et al., 2022).

Student readiness issues note that not all students have necessary digital literacy or self-regulation skills (Astalini et al., 2019; Dankbaar, 2017; Goode et al., 2022; Herbert et al., 2017; Rajabalee et al., 2020; Westerlaken et al., 2019). Orientation programs dan ongoing support suggested (Goode et al., 2022; Rajabalee et al., 2020). Assessment authenticity concerns related to ensuring online assessments measure intended outcomes (Astalini et al., 2019; Belfi et al., 2015; Debattista, 2018; Goode et al., 2022; McLaughlin et al., 2015; Noroozi & Mulder, 2017). Strategies include authentic performance-based assessments dan emphasis on formative assessment (Debattista, 2018; Noroozi & Mulder, 2017).

Conclusions

This systematic literature review of 18 high-quality studies (from 600 initial articles) demonstrates that integrated e-module and PjBL implementation significantly enhances engineering education outcomes across all learning domains: cognitive (+24.3%, d=1.42), affective (+22.7%, d=1.28), and psychomotor (+25.4%, d=1.51). The most effective e-module components identified include interactive video tutorials (88.9% adoption, 4.3/5.0 effectiveness), virtual simulations (77.8% adoption, 27% comprehension improvement), and authentic industry case studies (72.2% adoption, 4.6/5.0 relevance rating), while team-based PjBL projects spanning 6-8 weeks proved optimal for undergraduate engineering contexts. However, successful implementation requires addressing three critical challenges: development workload (83.3% of studies; requiring 120-180 hours per module), technical infrastructure limitations (77.8%; correlating with 18% lower engagement), and faculty digital competency gaps (66.7%; necessitating 20-40 hours professional development). Based on evidence synthesis, a five-module framework for Power Transfer Systems is proposed, integrating progressive PjBL complexity (from guided individual tasks to authentic team-based industry projects) with simulation-based learning, real-world failure analysis cases, and multi-method assessment strategies. Future research should prioritize longitudinal studies measuring long-term retention and workplace transfer, exploration of VR/AR technologies for hands-on skill development, AI-based adaptive learning systems, and cross-cultural comparative studies to advance evidence-based pedagogical innovation in technical education.

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