Proceedings of the 11th North American International Conference on Industrial Engineering and Operations Management, Milwaukee, Wisconsin, USA, June 9-11, 2026

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/NA11.20260082
Published: June 9, 2026

Active Learning and Systems Thinking in Product Development Process Education in Engineering

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Abstract

The education of the Product Development Process (PDP) is fundamental to the training of production engineers. However, its instruction frequently relies on linear and fragmented approaches, which often fail to convey its inherent systemic complexity. This paper presents an analysis of a pedagogical innovation implemented within an undergraduate Product Engineering course, wherein the PDP was explicitly framed and explored as a socio-technical system. The course redesign incorporated a comprehensive suite of active learning strategies, such as group debates, flipped classroom activities, collaborative mapping, system modeling, case-based learning, and a technical site visit. Employing a descriptive and qualitative methodology, data were gathered from student artifacts, assessments, and structured feedback mechanisms. The findings reveal an enhanced student comprehension of PDP phases, their interdependencies, and underlying systems principles, coupled with a high level of engagement in modeling and collaborative activities. Identified limitations include challenges associated with external partner engagement and temporal constraints. This study demonstrates that course-level pedagogical innovations can effectively foster a systemic understanding of PDP, offering valuable practical insights for engineering educators striving to modernize product development education.

Keywords
Product Development Process (PDP), Systems Thinking, Active Learning, Engineering Education, Pedagogical Innovation.

1. Introduction
The education of the Product Development Process (PDP) holds a pivotal role in the professional formation of production and industrial engineers. This is due to its comprehensive nature, encompassing critical competencies such as systems thinking, the integration of technical and organizational knowledge, decision-making under uncertainty, and navigating real-world constraints. In professional practice, engineers are expected not only to comprehend the sequential phases of product development but also to conceptualize, manage, and continuously refine PDPs as intricate socio-technical systems. These systems inherently involve the interplay of human resources, technologies, information flows, material considerations, and environmental factors. Despite this recognized importance, the pedagogy of product development within engineering curricula consistently encounters persistent challenges.

A persistent concern within the engineering education literature is the notable disconnect between theoretical instruction and the practical, systemic comprehension of design and product development. Conventional lecture-based pedagogies often prioritize prescriptive models, discrete tools, and isolated PDP phases. This approach inadvertently fosters a fragmented and linear perception among students regarding processes that are, in actuality, dynamic, highly interdependent, and inherently iterative. Although hands-on experiences are widely acknowledged as crucial, investigations into project-oriented and capstone courses reveal considerable variability in their implementation.

Consequently, many courses face difficulties in effectively integrating theory, practice, and reflective learning into a cohesive educational experience.

Active learning methodologies have been widely proposed as a potent response to these limitations. Evidence robustly suggests that student-centered strategies—including project-based learning, problem-based learning, case studies, structured debates, simulations, and flipped classrooms—can significantly enhance learning outcomes in engineering education, particularly when contrasted with purely expository approaches. Within the specific context of product development engineering, the judicious combination of active learning with structured reflection has been demonstrated to promote a deeper understanding of design processes, strengthen professional competencies, and markedly improve students' ability to transfer knowledge to novel contexts.

Beyond the active–passive dichotomy, another critical challenge resides in the limited explicit incorporation of systems thinking within engineering design education. Engineering curricula frequently fall short in treating systems thinking as a core competence, despite the fact that design and product development intrinsically necessitate an understanding of interactions, feedback loops, emergent properties, and trade-offs across multiple subsystems. When the PDP is taught as a mere sequence of disconnected stages, rather than as a system embedded within broader organizational, market, and societal contexts, students may struggle to grasp its full complexity and to diagnose failures as systemic design issues rather than isolated operational problems.

Recent scholarly work also highlights the inherent difficulty in imparting tacit and process-oriented aspects of design, such as decision rationale, iterative refinement, the negotiation of trade-offs, and learning from failure. Design reviews, expert coaching, and guided reflection are recognized as pivotal pedagogical components; however, they are often insufficiently structured or underexplored in typical engineering courses. Furthermore, while digital tools for system modeling and simulation are increasingly accessible, their integration into undergraduate product development courses remains constrained, frequently due to time limitations, tool complexity, or an inadequate pedagogical alignment.

Within this overarching context, a discernible research and practice gap emerges. Although the extant literature consistently advocates for the adoption of active, project-based, and system-oriented approaches in engineering education, empirical evidence remains limited on how these diverse elements can be coherently integrated within a singular undergraduate product development course, particularly within production engineering programs. Many studies tend to focus on capstone projects, isolated teaching methods, or curriculum-wide reforms, thereby leaving a void concerning course-level implementations that explicitly combine systems theory, active learning, and digital modeling tools.

This study directly addresses this identified gap by presenting and analyzing the implementation of an innovative pedagogical approach within an undergraduate Product Engineering course, part of a production engineering program at a large public university. The course redesign was meticulously developed as a component of an institutional teaching innovation initiative, specifically aiming to overcome the documented limitations of a previously traditional rendition of the discipline. The central premise was to conceptualize the Product Development Process as a comprehensive system, explicitly applying principles derived from General Systems Theory—such as interdependence, holism, feedback, equifinality, and entropy—through an integrated set of active learning strategies, real-world case studies, and advanced system modeling tools.

The primary objective of this study is to analyze how the integration of active learning methods—including group debates, flipped classroom activities, case-based learning, system modeling with digital tools, and technical visits—can enhance students' understanding of the PDP from a distinctly systemic perspective. Concomitantly, the study evaluates students' perceptions and learning outcomes associated with this multifaceted approach.

The main contribution of this work resides in its integrative and practice-oriented nature. Rather than focusing exclusively on capstone projects or isolated pedagogical techniques, this study elucidates how systems thinking, active learning, and digital modeling tools can be meaningfully articulated throughout an entire product development course. By synthesizing theoretical foundations, structured classroom activities, authentic industrial cases, and simulation-based exploration of feedback and dynamic system behavior, the study provides concrete empirical evidence of how

PDP education can be modernized to more accurately reflect the complexity inherent in contemporary engineering practice.

2. Theoretical Framework

Product development education plays a central role in project-oriented courses. The instruction of product design and product development in engineering is frequently operationalized through project-oriented courses, particularly integrative and capstone formats, which endeavor to immerse students in authentic problems and real-world constraints of design and implementation. Classical reviews and comprehensive surveys indicate that capstone courses are widely recognized as privileged venues for integrating technical knowledge and professional skills. However, they exhibit substantial variability in structure, assessment practices, and learning support strategies (Todd et al., 1995; Dutson et al., 1997). This variability underscores a recurring challenge: even when projects are adopted as the pedagogical backbone, the integration between theory, practice, and reflection is not always coherent, which can diminish the educational potential of PDP teaching when it is treated merely as a prescriptive sequence of stages.

2.1 Active learning methodologies and evidence of effectiveness in engineering education

The literature on engineering education has consolidated robust evidence indicating that active learning methodologies tend to yield superior outcomes compared to purely lecture-based approaches. This is particularly evident with respect to conceptual understanding, knowledge retention, and student engagement. Prince's (2004) seminal review is widely cited as a foundational reference supporting the adoption of strategies such as problem-based learning, project-based learning, case studies, debates, and collaborative activities, emphasizing that the *manner* in which students learn directly influences the *depth* of learning achieved. Within the specific field of product development engineering, Shekar (2007) reinforces the critical importance of combining active learning with structured reflection, positing that PDP education greatly benefits from pedagogical practices that explicitly articulate decision-making processes, trade-offs, and design reasoning throughout the entire development process, rather than concentrating solely on final outcomes.

2.2 PDP as a system: systems thinking as a core engineering competence

A central theoretical axis for effective PDP education is the understanding of product development as a socio-technical system. Such a system is inherently characterized by complex interdependencies, intricate feedback loops, dynamic behavior, and a multitude of often competing objectives (e.g., cost, performance, time, quality, and environmental impact). Dym (2004) cogently argues that engineering education must explicitly articulate design and systems perspectives, as design decisions inevitably propagate across various subsystems and organizational contexts. Complementarily, Godfrey et al. (2014) discuss how systems thinking and learning power—defined as the capacity to learn effectively within complex contexts—are essential for addressing contemporary engineering problems that demand integration and adaptive solutions. From this perspective, instructing PDP as a system, rather than as a linear sequence of discrete stages, aligns with a more realistic representation of engineering practice, where failures frequently emerge from systemic design decisions and interactions with the broader environment, rather than from isolated operational issues.

2.3 Teaching tacit competencies: coaching, design reviews, and feedback as learning mechanisms

Beyond the acquisition of conceptual knowledge, project-based courses must proactively foster tacit and process-oriented competencies. These competencies are inherently difficult to transmit through direct instruction and include, but are not limited to, decision justification, negotiation of trade-offs, iterative refinement, learning from failure, and effective technical communication. Research in Design Studies highlights that structured design reviews and expert coaching practices play a critical role in cultivating design reasoning. They provide opportune moments for students to externalize their decisions and receive expert mediation, thereby advancing the quality of both their thinking processes and their proposed solutions (Adams et al., 2016). This implies that the pedagogical design of PDP courses should intentionally incorporate structured feedback mechanisms—such as regular checkpoints, robust rubrics, guided reviews, self-assessment, and peer assessment—thereby mitigating reliance on implicit learning and significantly enhancing consistency in competency development.

2.4 Curriculum integration and alignment between objectives, activities, and assessment

The adoption of project-based learning frequently necessitates strong internal coherence and alignment among learning objectives, instructional activities, and assessment strategies. Paul et al. (2023), in their discussion of integrated PBL curriculum design, emphasize the paramount importance of aligning significant learning outcomes with assessment and instructional strategies over time. This approach avoids situations where projects are treated merely as final deliverables disconnected from the progressive development of competencies. In the context of PDP courses, this alignment translates into the imperative to combine individual and group assessments, formative and summative evaluations, and instruments capable of capturing both technical knowledge and students' ability to apply, analyze, and justify decisions within contexts that closely resemble professional practice.

2.5 From evidence to implementation: the research–practice gap in engineering education

Although the literature provides strong theoretical and empirical support for active learning, systems thinking, and authentic assessment, the consistent adoption of these approaches in practice faces notable institutional and cultural barriers. Finelli et al. (2014) explicitly discuss the persistent research–practice gap in engineering education, advocating for the strategic utilization of local evidence and meticulously structured institutional change planning to enable sustainable pedagogical transformations. Borrego and Henderson (2014) complement this perspective by comparing various strategies for increasing the use of evidence-based teaching in STEM education. They highlight that pedagogical improvement requires not only informed instructional choices but also supportive organizational conditions, appropriate incentives, robust support structures, and effective dissemination processes. Consequently, the implementation of innovations in a PDP course can also be interpreted as a situated educational intervention, critically dependent on a robust pedagogical design and operational feasibility, encompassing factors such as available time, necessary resources, enabling technologies, external partnerships, and adequate faculty preparation.

2.6 Synthesis of the theoretical framework and implications for PDP course design

In sum, the theoretical framework underscores several key tenets: (i) while project-oriented courses are indispensable for PDP education, they frequently exhibit heterogeneity and a lack of consistent integration (Todd et al., 1995; Dutson et al., 1997); (ii) active learning methodologies generally augment learning outcomes in engineering and hold particular promise for PDP when coupled with reflective practices (Prince, 2004; Shekar, 2007); (iii) conceptualizing PDP as a system is paramount for effectively addressing its inherent complexity and interdependencies (Dym, 2004; Godfrey et al., 2014); (iv) the development of tacit competencies necessitates structured coaching and robust feedback mechanisms (Adams et al., 2016); (v) project-based curricula and courses mandate a strong alignment among learning objectives, instructional activities, and assessment strategies (Paul et al., 2023); and (vi) the successful implementation of these practices hinges on bridging the research–practice gap and fostering supportive institutional conditions for change (Finelli et al., 2014; Borrego & Henderson, 2014). Collectively, these elements substantiate the imperative for pedagogical innovation within PDP courses, specifically those that seamlessly integrate systems thinking, active learning, digital tools, and thoughtfully designed assessment strategies.

3. Methodology

This study adopts a descriptive and applied educational research approach, grounded in the systematic documentation and rigorous analysis of a pedagogical innovation meticulously implemented in an undergraduate engineering course. The methodological design deliberately focuses on the implementation and comprehensive evaluation of teaching strategies within an authentic instructional context, precluding experimental manipulation.

3.1 Research Context

The study was conducted within the ambit of an institutional teaching innovation program and implemented in the undergraduate course *Engineering of Product I*, which is offered as part of a Production Engineering program at a large public university. The course spans 60 hours (equivalent to 4 credits) and enrolled 31 students in their fifth semester of the program. The pedagogical intervention was systematically applied throughout a full academic semester. The course redesign was specifically aimed at strengthening students' understanding of the Product Development Process (PDP) from a systems perspective. It addressed limitations previously observed in earlier iterations of the discipline, particularly concerning the prevalence of linear representations of PDP and the limited integration between theoretical content and its practical application.

3.2 Pedagogical Design and Instructional Strategies

The methodological approach comprised the implementation of a structured set of active learning strategies, carefully aligned with the course's learning objectives and progressively distributed over the semester. These strategies included:

- **Group debates and collaborative discussions** to elicit students' prior understanding of the role of the production engineer and the relevance of PDP.
- **Hands-on conceptual activities**, such as puzzle-based organization of PDP phases, meticulously designed to reinforce the objectives and expected outcomes of each phase.
- **Flipped classroom activities**, effectively supported by instructional videos and academic materials addressing principles of General Systems Theory, with student preparation rigorously assessed through structured online forms.
- **Case-based learning and collaborative mapping**, wherein students analyzed diverse products and industries using digital collaborative platforms to associate systems principles with specific PDP phases.
- **System modeling activities**, implemented using a causal-loop modeling tool, enabling students to construct and explore feedback structures within a simulated waste management system.
- **Analysis of real company cases**, supported by rich multimedia resources and guided worksheets, facilitating comparisons among distinct business models and various PDP configurations.
- **Technical site visit** to a product development company, preceded by the preparation of guiding questions and followed by structured activities in which students meticulously reconstructed the company's PDP and proposed opportunities for improvement.

3.3 Data Collection, Evaluation, and Analysis

Data collection was intrinsically embedded within the instructional process and relied upon multiple sources generated during the course. These sources included student responses to online forms, artifacts meticulously produced during classroom activities, formal written examinations, group presentations, and comprehensive reports related to case studies and the technical visit. Student perceptions regarding the pedagogical approach were systematically collected at the conclusion of the course using an interactive online feedback platform.

Student learning was evaluated through a combination of formative and summative assessments. This included written examinations, instructor- and peer-evaluated group presentations, and integrative assignments. Feedback was consistently provided throughout the semester via written comments and through dedicated digital learning environments.

Data analysis followed a qualitative and descriptive approach, specifically focusing on synthesizing empirical evidence from student artifacts, assessment results, and feedback data. The objective was to critically assess the coherence, practical feasibility, and overall educational value of the implemented pedagogical design.

4. Results and Discussion

4.1 Course Implementation and Overall Outcomes

The redesigned version of the course *Engineering of Product I* was fully implemented throughout the academic semester, with the active participation of all 31 enrolled students. The proposed pedagogical structure effectively enabled the execution of all planned activities and represented a significant departure from the previous, predominantly linear and lecture-based format. Instead, the course was strategically organized as a sequence of dynamic active learning experiences that repeatedly engaged students with the Product Development Process (PDP) from conceptual, systemic, and practical perspectives.

This overall outcome is consistent with the literature on project-oriented and design-focused engineering education, which consistently highlights the importance of repeated exposure to design concepts in varied contexts to support deeper learning and the effective integration of knowledge (Todd et al., 1995; Dutson et al., 1997). The implementation thus confirms the practical feasibility of articulating multiple active methodologies within the confines of a single undergraduate PDP course.

4.2 Conceptual Alignment and Early Engagement

The initial group debates unveiled heterogeneous and, in certain instances, fragmented student conceptions regarding the multifaceted role of the production engineer and the overarching relevance of PDP. Through structured discussion and a comparative analysis with formal professional definitions, students progressively converged toward a more refined understanding of engineering practice as inherently involving the design, management, and continuous improvement of integrated systems.

This result reinforces the empirical evidence that active, discussion-based activities are highly effective in eliciting prior knowledge and fostering conceptual realignment, as emphatically underscored in studies on active learning in engineering education (Prince, 2004). By explicitly establishing a linkage between professional identity and systems thinking, this activity significantly contributed to framing PDP as a complex socio-technical system, rather than a purely technical sequence of operations.

Figure 1 illustrates examples of student-generated conceptual maps and whiteboard panels.

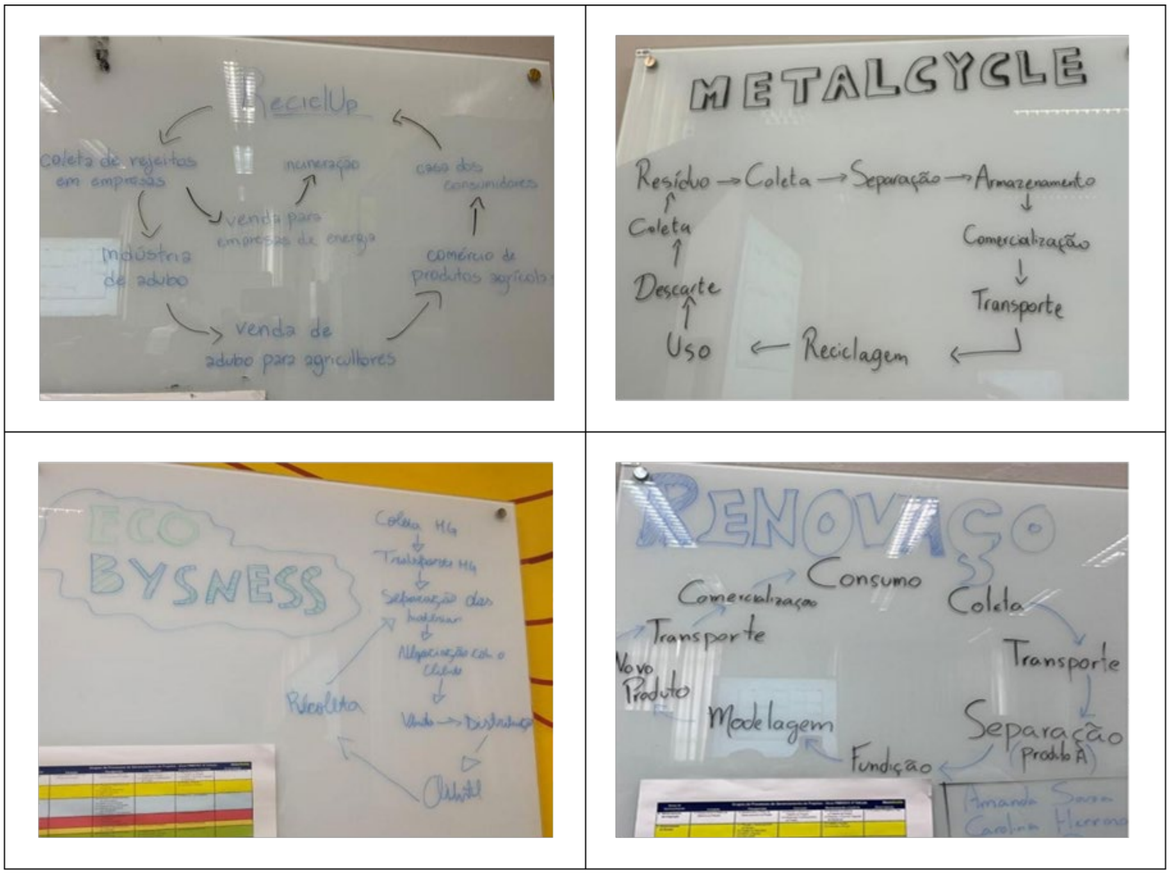

Figure 1. Examples of student-generated conceptual maps and whiteboard panels.

4.3 Understanding PDP Phases as an Interconnected System

The puzzle-based organization of PDP phases substantially supported students' understanding of the objectives, anticipated outputs, and intricate interdependencies of each phase. Instructor-guided corrections and peer group explanations consistently emphasized that PDP phases are not isolated steps, but rather intricately interconnected components of a broader, dynamic system.

These observations robustly align with Dym's (2004) argument that engineering design education must explicitly integrate design activities with systems thinking. Students' demonstrated ability to articulate complex relationships among PDP phases strongly suggests a substantive shift away from simplistic linear representations toward a more holistic and profoundly systemic understanding of product development.

Figure 2 presents examples of the puzzle-based PDP arrangements.

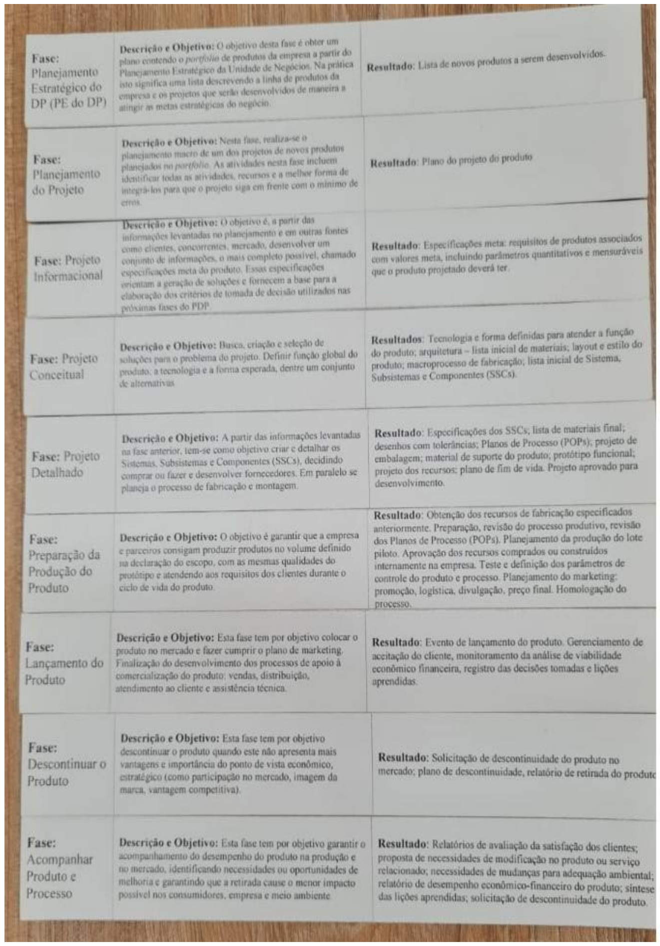

Figure 2. Examples of the puzzle-based PDP arrangements.

4.4 Application of Systems Theory through Flipped Classroom Activities

Student responses to structured online forms unequivocally demonstrated their nascent ability to identify and cogently describe core principles of General Systems Theory. These principles included interdependence, holism, equifinality, entropy, and feedback mechanisms. In-class activities subsequently required students to apply these abstract principles to concrete PDP-related examples, effectively supporting their transition from abstract theoretical definitions to a more contextualized and practical understanding.

This judicious combination of pre-class preparation and in-class application accurately reflects key recommendations from the literature on active learning and reflective practices within product development education (Prince, 2004; Shekar, 2007). The results clearly indicate that the flipped classroom approach significantly facilitated deeper engagement with complex systems concepts and their practical application within authentic engineering practice.

Figure 3 shows excerpts from student responses to systems theory questionnaires.

Figure 3. The systems theory questionnaire

4.5 Collaborative Mapping and Case-Based Reasoning

Collaborative digital mapping activities effectively enabled students to associate fundamental systems principles with specific PDP phases across a diverse range of products and industrial sectors. The digital boards meticulously produced by student groups unequivocally demonstrated their evolving capability to translate abstract systems concepts into concrete examples. For instance, they proficiently linked feedback mechanisms to iterative testing and validation processes, and expansionism to effective subsystem integration.

These compelling findings are consistent with Godfrey et al. (2014), who underscore the critical importance of contextualized learning activities for the effective development of systems thinking and enhanced learning power in engineering education. While variations in depth and clarity were naturally observed across different student groups, an overarching and discernible engagement with systemic reasoning was consistently evident.

Figure 4 illustrates representative excerpts from collaborative digital boards.

4.6 System Modeling and Visualization of Dynamic Behavior

The causal-loop modeling activity culminated in the creation of sophisticated system models that explicitly represented both reinforcing and balancing feedback loops within the specific context of waste management. Through this immersive activity, students gained the invaluable ability to visualize dynamic interactions and to critically explore how various interventions could profoundly influence overall system behavior.

This outcome strongly supports arguments articulated in the scholarly literature that system modeling and simulation tools can effectively render complex system behavior visible and significantly enhance learning outcomes in engineering education (Dym, 2004). The seamless integration of system modeling with earlier discussions on the circular economy and PDP ultimately strengthened the conceptual coherence across various interrelated course topics.

Figure 5 presents examples of causal-loop diagrams developed by student groups.

4.7 Real Company Cases and Technical Site Visit

The meticulous analysis of real company cases significantly supported students' understanding of how distinct organizational structures and prevailing business models profoundly shape PDP configurations. Comparative discussions revealed students' progressively growing ability to critically assess different approaches to product development, thereby reinforcing the inherent value of reflective and case-based learning within PDP education (Shekar, 2007).

The subsequent technical site visit afforded students the opportunity to reconstruct the PDP of an actual company and present their detailed analyses in class. However, consistent student feedback indicated that this activity proved less effective than others due to its predominantly oral and descriptive format, coupled with limited visual exposure to tangible development artifacts. This particular finding emphatically highlights the critical importance of structured interaction, expert coaching, and direct experiential engagement in design education, as extensively discussed by Adams et al. (2016).

Figure 6 includes photographs from the site visit and examples of student PDP reconstructions.

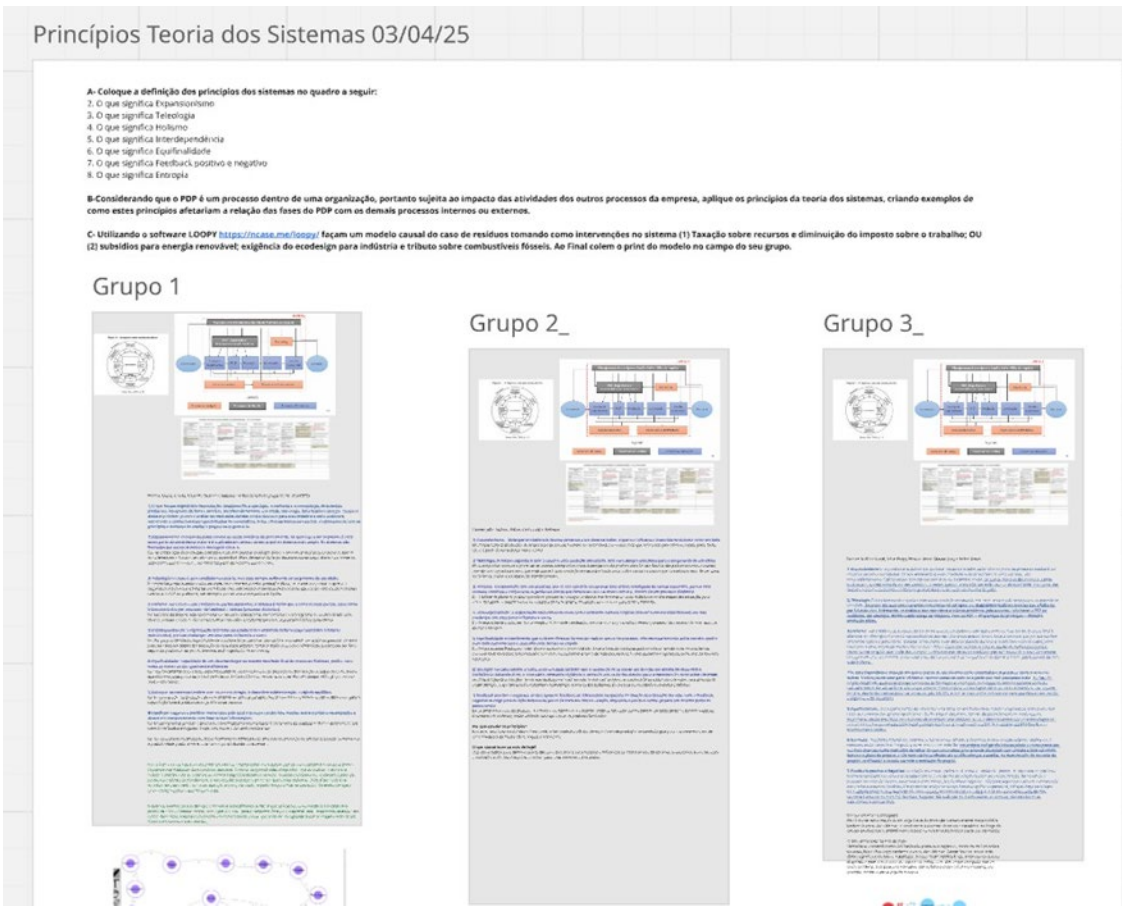

Figure 4. Representative excerpts from collaborative digital boards.

4.8 Assessment Results and Student Perceptions

Written examinations and comprehensive group presentations unequivocally demonstrated that students were proficient in articulating systems principles and applying them effectively to diverse PDP-related contexts. Feedback systematically collected through an interactive online platform indicated an overall positive perception of the adopted pedagogical approach. Notably, system modeling, collaborative mapping, and case-based activities were consistently identified as particularly efficacious for fostering profound learning.

In direct alignment with scholarly studies on the research–practice gap prevalent in engineering education, these results cogently suggest that well-designed, course-level pedagogical innovations possess the capacity to support meaningful improvements in student learning outcomes. Concomitantly, they also illuminate practical constraints invariably related to temporal limitations, tool complexity, and the intricacies of external collaboration (Finelli et al., 2014; Borrego & Henderson, 2014).

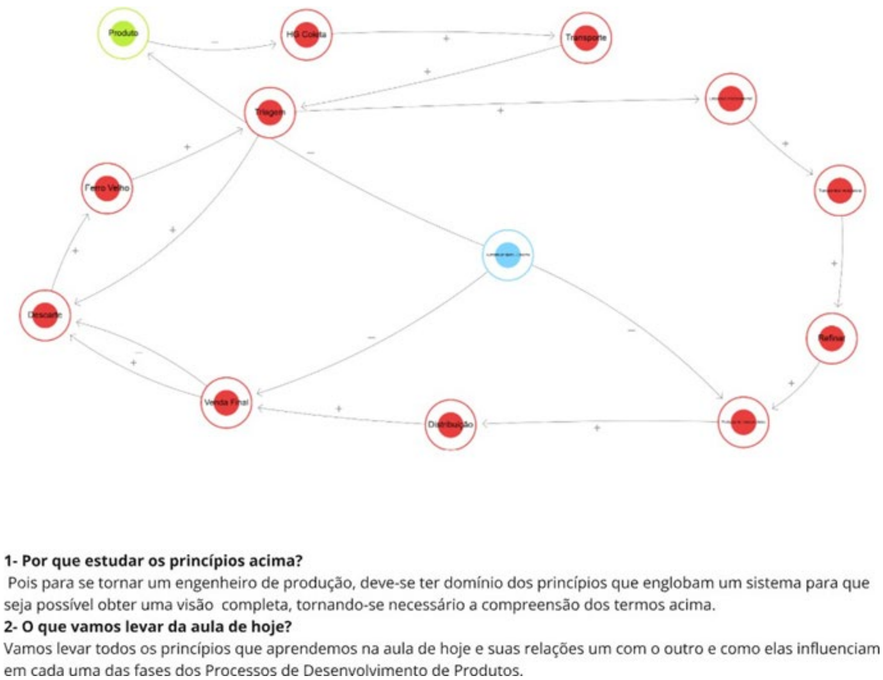

Figure 5. Examples of causal-loop diagrams developed by student groups.

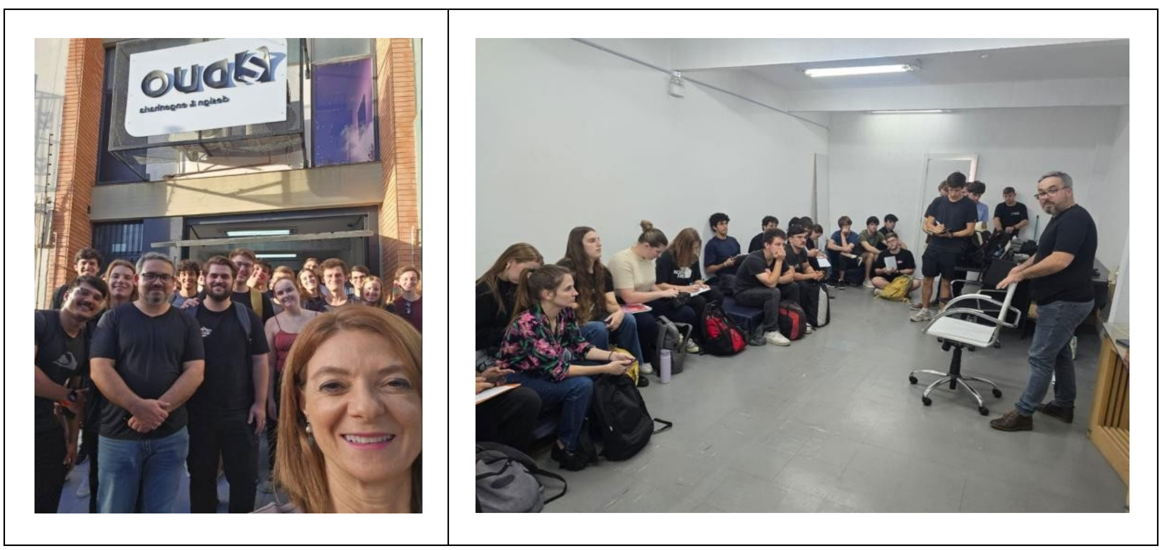

Figure 6. Photographs from the site visit and examples of student PDP reconstructions.

5. Final Considerations and Practical Implications

This study presented and rigorously analyzed the implementation of an innovative pedagogical approach within an undergraduate Product Development course, embedded within a Production Engineering program. This innovation was firmly grounded in the conceptualization of the Product Development Process (PDP) as a complex socio-technical system. The compelling results conclusively demonstrate that the proposed course redesign was not only feasible and internally coherent but also demonstrably capable of fostering a more integrated and profoundly systemic understanding of PDP, especially when juxtaposed against traditional, linear, and lecture-based instructional approaches.

The judicious combination of active learning strategies—including dynamic group debates, engaging flipped classroom activities, collaborative mapping exercises, insightful system modeling, comprehensive case-based learning, and an immersive technical site visit—empowered students to repeatedly engage with fundamental PDP concepts from multiple, enriching perspectives. Evidence meticulously gathered from classroom artifacts, formal assessments, and valuable student feedback consistently indicates that this repeated exposure significantly contributed to a deeper comprehension of PDP phases, their intricate interdependencies, and the overarching relevance of systems principles such as feedback mechanisms, holism, and mutual interdependence. These findings robustly reinforce the argument that PDP education substantially benefits from pedagogical designs that explicitly integrate systems thinking throughout the entire course curriculum, rather than treating it as an isolated or ancillary topic.

Concomitantly, the study also elucidated important limitations and crucial boundary conditions. The technical site visit, despite being conceptually well-aligned with the core course objectives, proved less efficacious due to its predominantly oral and descriptive format and a noted scarcity of interaction with tangible development artifacts. This particular outcome starkly highlights the inherent dependency of experiential learning activities on robust external partner engagement and a precise alignment with pedagogical goals. Additionally, temporal constraints and the intrinsic complexity of certain tools influenced the depth and breadth of some activities, particularly those pertaining to system modeling, thereby necessitating adaptive adjustments during the implementation phase.

From a practical perspective, several salient implications for contemporary engineering education can be rigorously derived. First, the results strongly suggest that course-level innovation—even when implemented without the scope of a large-scale curriculum reform—can substantially enhance learning outcomes, provided that pedagogical strategies are coherently aligned with established learning objectives and robust theoretical foundations. Second, the strategic utilization of simplified system modeling tools proved remarkably effective in introducing fundamental systems thinking concepts. Such tools can therefore be considered a viable and accessible entry point for undergraduate students, especially when more sophisticated software solutions are impractical or infeasible within typical course constraints. Third, dynamic active and collaborative learning environments, judiciously supported by intuitive digital platforms, demonstrably facilitate the articulation of abstract theoretical concepts and their practical application to authentic, real-world PDP contexts.

For instructors, this study unequivocally highlights the paramount importance of structured mediation and consistent feedback throughout project-oriented activities. Instructor-guided discussions, corrective interventions, and reflective exercises were critical in guiding students beyond superficial engagement towards a more robust and sophisticated systemic reasoning. For institutions, the findings underscore the imperative to actively support pedagogical innovation through the provision of adequate infrastructure, facilitated access to relevant digital tools, and the establishment of effective mechanisms for forging and sustaining strategic partnerships with external organizations.

In terms of broader implications, the educational experience meticulously documented in this study significantly contributes to ongoing scholarly discussions concerning the modernization of engineering education. It advocates for a closer alignment of teaching practices with the inherent complexity of contemporary engineering work. By treating PDP as a comprehensive system and deeply embedding this perspective across all learning activities, future engineers can be more effectively prepared to design, manage, and continuously improve product development processes within dynamic and inherently uncertain environments.

Future research endeavors may fruitfully build upon this reported experience by exploring the replication of this integrated approach in other courses or academic programs, systematically increasing the diversity of industrial partners involved, and further strengthening the seamless integration of advanced system modeling tools. Additionally, longitudinal studies could provide invaluable insights into how competencies developed within system-oriented PDP courses transfer to subsequent academic experiences or directly inform professional practice.

In conclusion, the pedagogical innovation comprehensively reported herein unequivocally demonstrates that integrating systems thinking, active learning, and real-world references within a singular PDP course is both eminently achievable and demonstrably beneficial. This provides substantial practical insights for educators and institutions steadfastly seeking to enhance engineering education in profound alignment with contemporary challenges.

Acknowledgements

The authors gratefully acknowledge the support of the Fulbright Program, whose funding and institutional collaboration made this work possible.

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Biographies

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