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Exploring a Project-Based Training Model for Engineering Undergraduates Driven by Model-Based Systems Engineering

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Abstract: Engineering undergraduate education is facing increasing challenges as emerging industries such as artificial intelligence, integrated circuits, and the low-altitude economy rapidly develop. Modern engineering practice involves highly information-intensive, interdisciplinary, and complex systems, placing higher demands on students' systems engineering capabilities. However, existing undergraduate engineering education models often suffer from insufficient industry-education integration and project-based teaching that lacks methodological support. To address these issues, this paper proposes a project-based training model driven by Model-Based Systems Engineering (MBSE), in which MBSE serves as the core methodological framework rather than a task or result-oriented supplement. An MBSE-lifecycle-driven framework is adopted to restructure project-based teaching, encompassing requirement capture, system modelling, subsystem design and integration, and verification and validation. The proposed model emphasizes process-oriented learning and systems thinking. Furthermore, a new industry-education collaboration mechanism with deep enterprise participation and a multi-perspective evaluation system based on MBSE process artifacts are established. The proposed approach provides a systematic pathway for enhancing undergraduates' ability to solve complex engineering problems and offers a replicable paradigm for engineering education reform and talent cultivation in emerging industries.

1. Challenges in engineering undergraduate education

With the rapid development of industries such as artificial intelligence, integrated circuits, and the low-altitude economy, the training pathways and models for engineering talent are shifting from traditional knowledge-oriented teaching toward active, learner-centered approaches. Upon entering the workforce, engineering graduates are increasingly required to deal with information-intensive, interdisciplinary, and complex engineering systems, which impose higher demands on their systems engineering competencies. Consequently, conventional undergraduate engineering education models are facing significant challenges.

1.1. Insufficient depth of industry-education integration

Although many universities have established industry-oriented colleges or programs in collaboration with enterprises—where companies participate in curriculum design or propose capstone project topics—the outcomes are often limited. Students still tend to passively accept predefined tasks, lacking a holistic and systemic understanding of engineering problems. Their ability to analyze system requirements, define functional boundaries, and design system architectures remains weak, leading to an overemphasis on isolated technical solutions while neglecting system-level considerations.

1.2. Neglect of methodology in traditional project-based teaching

Some universities have introduced project-based courses into engineering practice environments [1], such as microcontroller experiments or project-oriented laboratory work. However, most of these projects remain task-driven or problem-oriented and lack systematic engineering methodology support. Project implementation often relies heavily on experience, instruction, and trial-and-error approaches [2], with limited emphasis on system modelling, architectural reasoning, or verification methods. As a result, such projects fail to effectively cultivate students' ability to address complex systems engineering problems.

2. Overall MBSE-driven project-based training approach

To overcome the aforementioned limitations, this paper proposes adopting MBSE as the core methodological foundation for project-based training in undergraduate engineering education [3]. Instead of being driven by predefined tasks or expected outcomes, the proposed approach is methodology-driven, aiming to reconstruct the paradigm of project-based teaching through systematic engineering principles.

2.1. Introducing MBSE into engineering education practice

MBSE emerged around 2010 and remains a frontier topic in the field of systems engineering. It has been widely adopted by large industrial enterprises as a key methodology for product development and process management [4]. MBSE emphasizes the use of system models as the primary means of engineering development, supporting requirement analysis, functional decomposition, system architecture design, and verification and validation throughout the entire project lifecycle. Key MBSE activities include:

(1) Requirement modeling: transforming stakeholder needs into structured, traceable system requirements.

(2) Functional modeling: defining system functions and performing hierarchical decomposition and allocation.

(3) Architecture modeling: establishing logical and physical system architectures.

(4) Verification and validation: ensuring consistency between system design and requirements through model-based methods.

Integrating these principles into undergraduate project-based teaching helps students develop a comprehensive systems perspective and shift from goal-driven project thinking to systems-oriented engineering reasoning [5].

2.2. Reconstructing project-based teaching based on the MBSE process

Unlike traditional project-based teaching, the proposed training model is explicitly structured around the MBSE workflow, enabling a process-oriented design of teaching activities. As shown in Figure 1, the main stages include:

(1) Requirement capture phase: Enterprises propose real engineering backgrounds or product application scenarios instead of directly assigning project topics. Under joint guidance from enterprise and academic mentors, students conduct requirement analysis and preliminary requirement modelling, which are subsequently reviewed and refined by mentors.

(2) System modelling phase: Based on requirement models, students perform functional decomposition and develop high-level logical architectures and detailed physical architectures.

(3) Subsystem design and integration phase: Subsystem design and implementation are strictly aligned with system models, preventing out-of-scope development and ensuring architectural consistency.

(4) Verification and evaluation phase: System verification is conducted by tracing back to requirement models, enabling comprehensive assessment of engineering implementation and outcomes.

Through this process, predefined results and outcome-oriented thinking are replaced by methodological learning and process-oriented practice. Students gain a holistic understanding of engineering practice, reducing the limitations imposed by passive learning and fostering creativity and systems engineering competence.

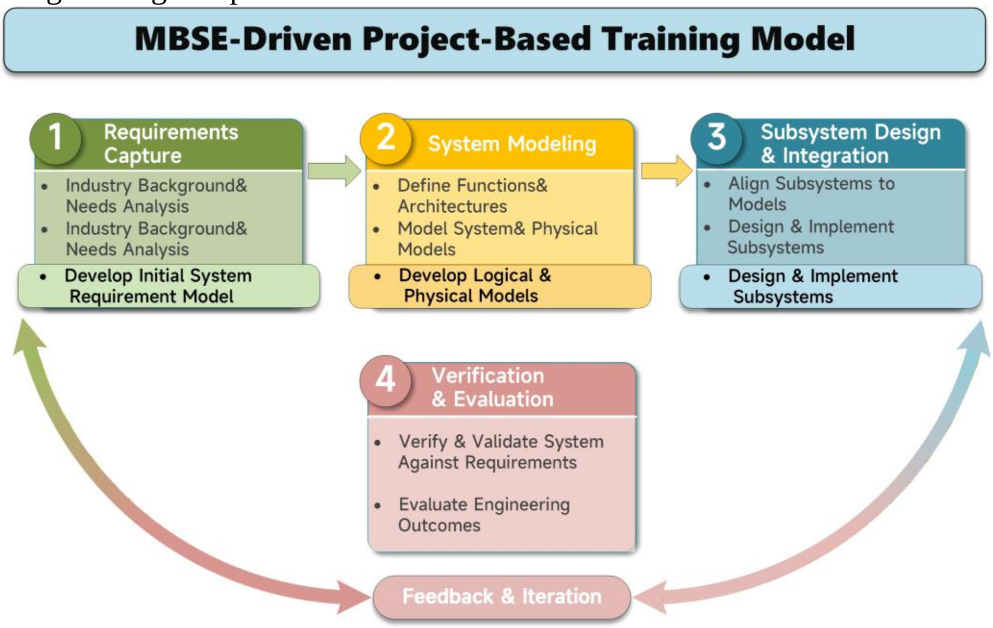

Figure 1: MBSE-driven project-based training model.

3. MBSE-based industry–education integrated project implementation

3.1. New requirements for enterprise participation

In the MBSE-driven project-based training model, enterprises are no longer simple providers of requirements or project goals. Instead, they act as active participants throughout the system engineering lifecycle, deeply engaging in all practical stages. As shown in Figure 2, this approach lays the foundation for cultivating truly industry-ready engineering talent while imposing new requirements on enterprise participation:

- Emphasizing the accumulation of product or service requirements and precise definition of boundary conditions.
- Participating in requirement reviews, architecture reviews, subsystem design reviews, and acceptance evaluations.
- Contributing to project quality and effectiveness assessment based on product or service requirements.
- Using the educational process as a reflective case source for generating new enterprise requirements.

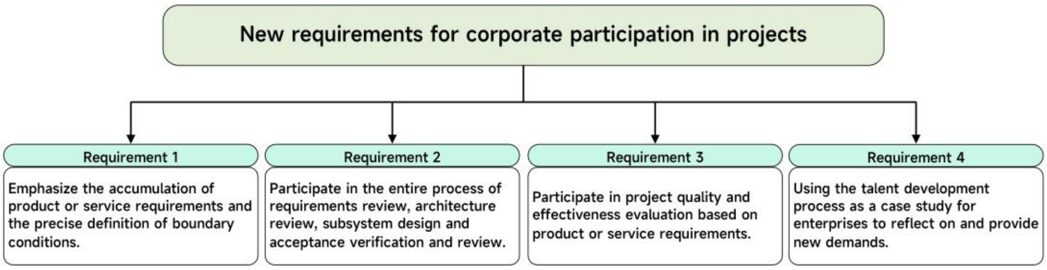

Figure 2: New requirements for corporate participation in projects.

These measures establish a comprehensive communication bridge between enterprises and students, enhancing students' employment prospects while enabling enterprises to cultivate the engineering talent they genuinely need.

3.2. A new collaborative mechanism for academic and enterprise mentors

To effectively implement the proposed methodology, academic mentors are required to systematically enhance their understanding of MBSE theory and practice, with particular emphasis on process-oriented project management. Their role is to guide students toward developing project manager–level engineering competencies. Enterprise mentors, on the other hand, focus on requirement accumulation and validation, continuously improving their expertise in feasibility analysis, development standards, and application value. The synergy between academic and enterprise mentors enables students to receive comprehensive training from theoretical foundations to real-world engineering practice.

4. Establishing an MBSE-driven project evaluation system

Achieving effective MBSE-driven project-based teaching evaluation requires breaking away from traditional result-dominated assessment models. Greater emphasis should be placed on students' performance across different process stages to support reflection and continuous improvement.

4.1. Stage-based evaluation of MBSE process artifacts

Students' outputs at different stages of the MBSE-driven project are used as evaluation objects, including system requirement models, functional decomposition models, system architecture models, interface integration models, and final verification reports. By conducting stage-based checks on documentation consistency and traceability, rather than focusing excessively on final physical prototypes—students' understanding of systems engineering processes is strengthened. This approach effectively addresses the common issue of "build first, document later" and promotes systematic engineering competence development.

4.2. Multi-perspective comprehensive evaluations

A multi-perspective evaluation mechanism is established by combining assessments from academic mentors, enterprise mentors, and student teams' self-evaluations. Academic mentors focus on students' mastery of MBSE theory and process application, while enterprise mentors emphasize the completeness, rationality, and requirement alignment of project outputs. Peer evaluation among student teams enables learners to identify collaboration issues across different projects, fostering reflection and improvement. As shown in Figure 3, this multi-perspective approach provides a more comprehensive and objective evaluation of project-based teaching effectiveness.

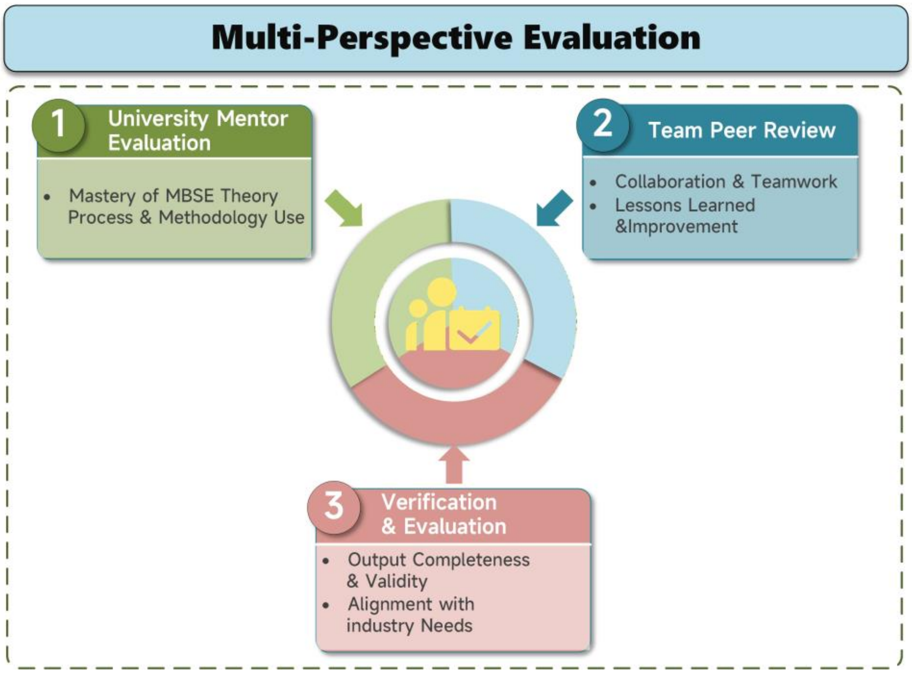

Figure 3: Multi-perspective evaluation model.

5. Conclusions

This paper addresses the challenges of insufficient industry-education integration and limited effectiveness of traditional project-based teaching in engineering undergraduate education. An MBSE-driven project-based training model is proposed, featuring three major innovations. First, advanced MBSE theory is introduced into undergraduate engineering education, reshaping project-based teaching through a model-driven and standardized workflow of requirements, functions, architectures, and verification, thereby strengthening students' systems engineering thinking. Second, an industry-education integration mechanism with deep enterprise participation across the entire project lifecycle is established, shifting the training process from task-oriented to methodology-oriented learning. Third, a dynamic evaluation system based on MBSE process artifacts and multi-perspective assessment is developed, emphasizing process rigor and capability development. The proposed model provides a systematic pathway for enhancing engineering students' ability to solve complex engineering problems and offers a replicable paradigm for curriculum reform and enterprise-oriented training in emerging industries such as artificial intelligence and advanced manufacturing.

Acknowledgements

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References

[1] Kokotsaki D, Menzies V, Wiggins A. Project-based learning: A review of the literature[J]. Improving schools, 2016, 19(3): 267-277.

[2] Boss S, Larmer J. Project based teaching: How to create rigorous and engaging learning experiences[M]. ASCD, 2018.

[3] Henderson K, Salado A. Value and benefits of model-based systems engineering (MBSE): Evidence from the literature[J]. Systems Engineering, 2021, 24(1): 51-66.

[4] Berschik M C, Schumacher T, Laukotka F N, et al. MBSE within the engineering design community–an exploratory study[J]. Proceedings of the Design Society, 2023, 3: 2595-2604.

[5] Forlingieri M, Paw Y C. Integrating PLE to Enhance MBSE Education in Emerging Engineering Countries: The Example of Singapore Institute of Technology[C]//INCOSE International Symposium. 2025, 35(1): 89-103.