Reshaping Engineering Education: Addressing Complex Human Challenges: A Book Review

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Avelinah Julius & Mohamad Syahrul Nizam Ibrahim*
Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah,
Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia
**syahrul@ums.edu.my*

Abstract
Reshaping Engineering Education: Addressing Complex Human Challenges, authored by Fawwaz Habbal, Anette Kolmos, Roger G. Hadgraft, Jette Egelund Holgaard, and Kamar Reda, addresses the urgent need for transformative changes in engineering education. The authors argue that the traditional curriculum, primarily focused on mathematical rigour and applied sciences, is insufficient to equip graduates for the complex, interdisciplinary challenges of the modern world. These challenges, such as global sustainability, climate change, and the digital revolution, require holistic, systems-thinking approaches. The book is structured into four main sections. Part I highlights the importance of systems thinking and design methodologies in engineering education, positioning engineers as problem-solvers in complex real-world systems. Part II explores pedagogical changes, advocating for problem-based and project-based learning as key methods to foster critical thinking and creativity. Part III presents case studies from Harvard University, Aalborg University, and the University of Technology Sydney, demonstrating successful applications of these educational reforms. Part IV concludes with actionable recommendations for institutions to integrate interdisciplinary and design-focused curricula. Through its examination of innovative teaching strategies and case studies, the book emphasizes the need for collaboration, adaptability, and interdisciplinary learning in modern engineering education. It offers a comprehensive framework for reshaping engineering programs and preparing future engineers with the skills necessary to tackle complex human challenges.

Keywords: Systems thinking, interdisciplinary learning, problem-based learning, project-based learning, curriculum transformation.

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Introduction

In a world where engineering challenges are becoming increasingly complex, interdisciplinary, and global in scope, *Reshaping Engineering Education: Addressing Complex Human Challenges* offers a transformative vision for the future of engineering education. Authored by a distinguished group of academics—Fawwaz Habbal, Anette Kolmos, Roger G. Hadgraft, Jette Egelund Holgaard, and Kamar Reda—the book emphasises the need to shift from traditional technical education to one that promotes systems thinking, interdisciplinary collaboration, and innovative problem-solving.

The authors bring a wealth of experience and achievements to this work, making it an authoritative guide on educational reform. Fawwaz Habbal, a senior lecturer at Harvard University's School of Engineering and Applied Sciences, has successfully implemented innovative pedagogical strategies like studio-based learning. His involvement in founding the Harvard Learning Incubator and co-directing the Master in Design Engineering (MDE) program highlights his commitment to integrating design thinking into engineering education.

Anette Kolmos, a professor at Aalborg University and a leading figure in engineering education research, has extensively studied Problem-Based Learning (PBL) and Project-Based Learning (PjBL). Her role as the Founding Director of the UNESCO Centre for Problem-Based Learning in Engineering Science and Sustainability underscores her influence on global educational practices.

Roger G. Hadgraft, a civil engineer with over 30 years of experience, is known for reforming engineering curricula to integrate project-based learning. His leadership in introducing interdisciplinary programs at institutions such as Monash University and the University of Technology Sydney reflects his innovative approach to engineering education.

Jette Egelund Holgaard, also from Aalborg University, has contributed significantly to research on sustainability and interdisciplinary education in

engineering, while Kamar Reda's work in bioengineering at Harvard focuses on systems thinking and its application in solving complex human challenges.

Together, these authors argue that the traditional, mathematically focused engineering curriculum is insufficient for addressing today's multifaceted global challenges, such as climate change, digitalization, and sustainability. The book also highlights the role of policymakers—those who shape educational policies and curricula at national and institutional levels—in driving this transformation. Relevant policymakers include educational ministries, such as the U.S. Department of Education or the European Commission's Directorate-General for Education, Youth, Sport and Culture, as well as accreditation bodies like ABET, which set standards for engineering programs. Governmental agencies responsible for workforce development, such as the National Science Foundation (NSF) or similar bodies globally, are also key stakeholders who can benefit from the insights offered in this book. This makes the book an essential resource not only for educators and researchers but also for policymakers seeking to align engineering education with the needs of a rapidly evolving, interdisciplinary world.

Summary and opinions

Summary of Key Themes

The authors structure the book into four parts: *Systems Thinking and Design, Learning Processes for Students and Academics, Case Studies from International Universities,* and *Recommendations for Implementing Change*. In Part I, the authors emphasize the growing complexity of human challenges and the critical role systems thinking plays in addressing these issues. Systems thinking encourages engineers to view problems as interconnected, involving technical, social, and environmental elements, which must be addressed collectively rather than in isolation. The authors argue that this approach is vital for developing solutions that are sustainable and scalable.

Part II delves into the learning processes needed to cultivate systems thinkers. It emphasizes that both students and academics must adopt new pedagogies that prioritize problem-based learning (PBL) and project-based learning (PjBL). These methods encourage active learning, critical thinking, and real-world problem-solving, all of which are crucial in today's engineering landscape. By transforming how engineering students learn and engage with complex challenges, institutions can better prepare graduates for the interdisciplinary demands of modern engineering. However, implementing PBL and PjBL methodologies is not without challenges. For instance, scaling these pedagogies across diverse educational contexts can be hindered by varying institutional support, faculty readiness, and student engagement levels (Hmelo-Silver, 2004). While this book highlights the transformative potential of PBL and PjBL, the implementation of these methodologies faces significant barriers. Faculty often require substantial retraining to transition from traditional lecture-based teaching to interactive learning methods. Moreover, students may resist active learning due to unfamiliarity, preferring the structure of conventional instruction.

To address these challenges, adaptable frameworks tailored to institutional contexts are needed. For example, modular PBL structures can be integrated into existing curricula with minimal disruption. Additionally, faculty development programs, such as peer-mentoring initiatives and workshops focusing on active learning strategies, can bridge gaps in readiness. Studies like those by Peña & de les Valls (2023) underscore the effectiveness of such tailored professional development programs in improving educational outcomes.

Part III presents a series of case studies from universities in the United States, Denmark, and Australia, illustrating how different institutions have adopted these pedagogies. For example, Harvard University's engineering program focuses on design thinking and interdisciplinary collaboration, while Aalborg University in Denmark implements a problem-based approach that emphasizes teamwork and societal impact. These case studies serve as valuable examples of how diverse institutional contexts can adopt similar approaches to achieve successful educational outcomes.

Finally, Part IV offers ten key recommendations for institutions looking to reshape their engineering curricula. These include adopting design-oriented and interdisciplinary approaches, focusing on societal needs, and fostering environments that promote active, hands-on learning. The recommendations provide practical steps for universities to begin transforming their programs, making this section an actionable guide for future reforms.

Detailed Discussion on Part II: Learning processes for both students and academics

Although all sections offer valuable insights, Part II emerges as particularly critical for advancing research in engineering education. This part not only explores the pedagogical shift required to cultivate systems thinking and interdisciplinary collaboration but also highlights the importance of changing both student and academic mindsets to foster creativity, adaptability, and problem-solving skills.

One of the key takeaways from this section is the potential of PBL and PjBL to create more engaging and effective educational environments. These pedagogies place students at the centre of their learning, encouraging them to tackle real-world problems in collaborative settings. By working on authentic,

complex challenges, students develop the critical thinking and teamwork skills that are essential for modern engineers. Moreover, these methods allow for the integration of multiple disciplines, reflecting the interconnected nature of today's engineering problems.

In our opinion, PBL and PjBL are crucial to making engineering education more dynamic and relevant in today's world. These methods align well with the increasing complexity of global challenges, which require engineers to possess not only technical expertise but also the ability to work effectively in teams and across disciplines. For example, Guerra et al. (2023) conducted a qualitative study examining the impact of PBL on critical thinking, collaboration, and real-world problem-solving skills among engineering students. By focusing on interdisciplinary team projects, their research demonstrated how PBL fosters adaptability and creativity—skills that are often underdeveloped in traditional engineering curricula. This evidence reinforces the argument that PBL is a crucial pedagogical approach for modern engineering education.

For future research, there is a need to explore how these active learning environments can be further optimized to support diverse learning styles and needs. Studies by Hmelo-Silver (2004) and Chen et al. (2023) emphasize the importance of adapting PBL to different contexts and student demographics, but more work is required to understand the long-term impacts of these pedagogies, particularly in terms of employability, innovation, and leadership in interdisciplinary teams. Additionally, the role of technology in enhancing these learning processes—such as using artificial intelligence (AI), big data, and digital simulations—offers fertile ground for future studies. As the book suggests, integrating advanced technologies into engineering curricula can provide students with the tools they need to address complex systems more effectively (Du et al., 2022). Emerging technologies, such as artificial intelligence (AI) and digital simulations, offer significant potential to address the complexities of modern engineering education. AI-powered adaptive learning platforms, as discussed by Chen et al. (2023), can personalize content to help students learn at their own pace while addressing individual gaps. Similarly, AI tools for teamwork, like natural language processing (NLP) applications, enhance collaboration by summarizing technical documents, managing timelines, and improving communication.

Digital simulations further enrich the learning experience by immersing students in realistic, risk-free environments. For instance, civil engineering simulations allow students to design and test infrastructure projects using real-time data, fostering critical thinking and problem-solving skills (Hmelo-Silver, 2004). Future research should focus on the long-term impacts of these tools on skill development, employability, and innovation capacity.Another critical area for future research is the impact of these pedagogies on diversity in engineering education. As engineering programs around the world continue to struggle with gender and racial disparities, understanding how PBL and PjBL can create more inclusive learning environments is of utmost importance. Research should focus on how these methodologies affect underrepresented groups in STEM and whether they can help close the gap in participation and success for women and minorities in engineering fields. Felder & Brent (2007) argue that cooperative learning environments like PBL can help reduce the sense of isolation often felt by underrepresented students, fostering a more inclusive atmosphere.

Finally, the role of educators in this transformation cannot be overlooked. Part II emphasizes that faculty must also adapt to new teaching methods and mindsets. Future research should examine the most effective ways to train and support educators as they implement these pedagogies. This could include exploring professional development programs, peer mentoring, and other support systems that enable educators to successfully shift from traditional lecture-based teaching to more interactive, student-centred approaches. According to Peña & de les Valls (2023), professional development in PBL and PjBL has proven effective in improving teaching practices and aligning them with contemporary educational goals.

Conclusion

In conclusion, the book *Reshaping Engineering Education: Addressing Complex Human Challenges* compellingly advocates for a reimagined approach to educating future engineers. The systems-based approach and emphasis on interdisciplinary learning outlined in the book provide a comprehensive framework for educational reform. Part II, in particular, offers valuable insights into the pedagogical shifts needed to prepare students for the challenges of the 21st century, making it a prime area for future research. By continuing to explore how PBL, PjBL, and digital technologies can enhance learning and promote diversity, researchers and educators can contribute to creating more effective and equitable engineering education systems. This book serves as an essential guide for anyone involved in engineering education reform and provides a solid foundation for future studies. This book serves as an indispensable resource for educators, policymakers, and curriculum designers. For educators, it offers actionable insights on adopting and scaling PBL and PjBL methodologies to enhance student engagement and learning outcomes. Policymakers, in turn, can utilize the book's recommendations to better align engineering curricula with global workforce demands, fostering interdisciplinary competencies that address societal challenges.

Curriculum designers, particularly those in accreditation agencies like ABET, can leverage its frameworks to develop standards emphasizing hands-on, systems-thinking approaches. Collectively, these stakeholders can drive the systemic changes necessary to reshape engineering education and prepare future engineers for the demands of the 21st century.

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Conflict of Interest

The authors declare no conflict of interest.

References

Chen, J., Du, X., Chaaban, Y., Velmurugan, G., Lyngdorf, N., Norgaard, B., et al. (2023). An exploration of sources fostering first-year engineering students' academic well-being in a PBL environment. IEEE Transactions on Education, PP, 1–10. https://doi.org/10.1109/TE.2023.3273352

Du, X., Lyngdorf, N., Guerra, A., Hansen, S., & Bertel, L. (2022). Gender and Diversity in a Problem and Project-Based Learning Environment. CRC Press.

Felder, R. M., & Brent, R. (2007). Cooperative learning. Active Learning: Models from the Analytical Sciences, ACS Symposium Series, vol. 970, 34–53.

Guerra, A., Kolmos, A., & Lyngdorf, N. (2023). Problem-based learning and interdisciplinarity: Towards understanding diversity in engineering education. European Journal of Engineering Education, 1–13. https://doi.org/10.1080/03043797.2023.1285782

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? Educational Psychology Review, 16(3), 235-266.

Peña, M., & de les Valls, E. M. (2023). Inclusion of the gender equality sustainable development goal in engineering teaching and research. Environment, Development and Sustainability, 1–15. https://doi.org/10.1007/s10668-023-03667-2.