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Vision, Challenges, and Research Issues in Digital Education and Learning Engineering

Sasithorn Chookaew[1] & Patcharin Panjaburee[2*]

Faculty of Technical Education, King Mongkut's University of Technology North Bangkok, Thailand [1], Faculty of Education, Khon Kaen University, Thailand [2*]

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Abstract

Digital Education and Learning Engineering (DELE) has emerged as a transformative discipline, combining educational theories with data-driven technologies to optimize learning experiences and outcomes. On the other hands, learning engineering, as a systematic approach to designing, implementing, and refining educational technologies, is crucial in bridging the gap between pedagogy and technology. This paper defines learning engineering as an iterative, interdisciplinary process that leverages education, computer science, and engineering insights to create learning environments for all educational levels. The significance of this approach lies in its ability to design solutions that respond to the unique educational settings of diverse learners while continuously improving learning performance. We explore the vision for DELE as a key enabler of innovative education systems and outline the critical challenges, such as scalability, ethical concerns, and the integration of digital infrastructures. A framework is proposed to guide researchers and practitioners in applying learning engineering principles to real-world educational contexts. In addition, we identify potential research topics that need to be addressed to ensure DELE's sustained impact on the future of education. Finally, we discuss the types of contributions that this field seeks to advance both the theoretical and practical aspects of digital learning systems.

Keywords: Innovative learning, lifelong learning, quality education

■ Vision and Challenges of Digital Education and Learning Engineering

DELE has emerged as a transformative discipline driven by the rapid integration of digital technologies in educational environments. DELE combines insights from education, engineering, and

*Corresponding author
Email address: patchapan@kku.ac.th

computer science to develop and implement technology-enhanced learning systems that address the evolving needs of learners and educators. The overarching vision of DELE is to leverage digital tools and techniques to enhance the teaching and learning experience, foster learning, and promote equitable access to educational opportunities. One of the primary challenges in DELE is the complexity of adapting digital technologies to diverse educational contexts. With the principle of a learning engineering approach, it is challenging to design, implement, and refine educational technologies to bridge the gap between pedagogy and technology (Kolodner, 2023**;** Lee, 2023**;** Rivadeneira & Inga, 2023). Educators and institutions must navigate a constantly evolving landscape of digital tools, each with its affordances and limitations. Effectively integrating these technologies requires a deep understanding of pedagogical principles, learner needs, and the capabilities of the available digital solutions (Alamri et al., 2021; Timotheou et al., 2023). Another crucial challenge is the need for robust digital infrastructure to support the implementation and scalability of DELE systems. This includes ensuring reliable connectivity, hardware, software, and data management capabilities to enable seamless and secure digital learning experiences. Additionally, integrating data-driven practices is essential for DELE, as it allows for the continuous improvement of learning systems and the personalization of educational experiences (Yang & Ogata, 2023; Komalawardhana & Panjaburee, 2024). However, the effective use of data in education raises important questions about data privacy, ethics, and the responsible application of these technologies (Mathrani et al., 2021; Ashok et al. 2022; Hillman, 2023).

In the following sections, we propose a framework for clarifying DELE as well as the definition of DELE. We discuss research topics in DELE in the area of articles that are of interest in this journal and guide researchers and school teachers who intend to study, implement, or apply applications relevant to DELE in the future.

■ Framework of Digital Education and Learning Engineering

The development of a comprehensive framework for DELE is essential to guide both researchers and practitioners in systematically applying and evaluating the principles of learning engineering within educational settings. The DELE framework integrates interdisciplinary perspectives from education, computer science, and engineering to design, implement, and refine educational systems that meet the evolving needs of diverse learners and institutions. This framework is built on three foundational pillars: pedagogical alignment, technological adaptability, and data-driven optimization, as shown in Figure 1.

(1) Pedagogical Alignment: At the core of the DELE framework is the alignment between technology and pedagogy. It emphasizes that the design and implementation of educational technologies must be driven by sound pedagogical principles. Educational theories—such as constructivism, behaviorism, and social learning theory—must inform the development of digital tools and learning environments. A successful DELE system ensures that technology serves as a facilitator of learning, rather than a distraction or barrier. This alignment requires an understanding of both the educational goals and the specific needs

of the learners, ensuring that digital solutions are tailored to foster engagement, critical thinking, collaboration, and knowledge retention.

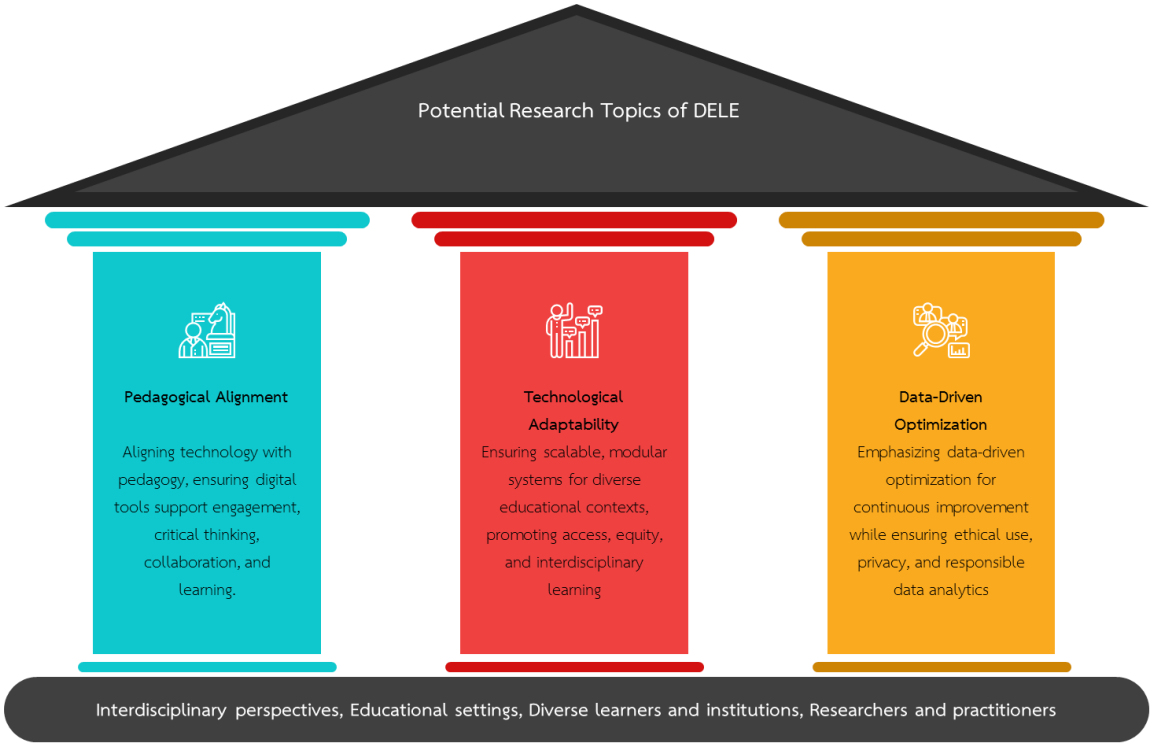

Figure *1*. Three Foundational Pillars of Digital Education and Learning Engineering

(2) Technological Adaptability: The second pillar of the DELE framework focuses on the adaptability of technology to diverse educational contexts. In an era of rapid technological advancement, educators and technologists must remain flexible and open to integrating new tools that align with the learning objectives. This adaptability includes the design of scalable systems that can function in varying learning environments—whether formal classrooms, online courses, or hybrid setups. The DELE framework encourages the creation of modular systems that can be customized to different learning scenarios, supporting not only traditional academic subjects but also interdisciplinary and vocational training. Importantly, it addresses the need for robust digital infrastructures to ensure access and equity across educational settings, particularly in under-resourced regions.

(3) Data-Driven Optimization: A defining feature of the DELE framework is the emphasis on continuous improvement through data-driven optimization. Learning engineering approaches advocate for the collection and analysis of data to refine educational systems over time. Data on student engagement, performance, and learning outcomes should be leveraged to personalize learning experiences and provide timely feedback to learners and educators. However, this approach also raises significant ethical considerations regarding privacy, data security, and the potential misuse of student data. The DELE framework calls for the responsible use of data analytics to support decision-making, while safeguarding the rights of learners and adhering to ethical standards.

By adhering to the principles outlined in the DELE framework, educators and researchers can create learning systems that are not only technologically sophisticated but also pedagogically sound and ethically responsible. This approach ensures that digital education continues to evolve in ways that enhance learning outcomes, foster inclusivity, and promote equitable access to educational resources.

■ Potential Research Topics of Interest in this Journal

As mentioned above, this journal focuses on advancing DELE through diverse research areas that address the evolving needs of modern education systems. Key topics include ensuring equitable access to digital education by overcoming socio-economic and geographic barriers, fostering interdisciplinary collaboration among educators and technologists to enhance DELE development, and integrating cutting-edge technologies. Additionally, the journal encourages research on empowering educators through professional development in DELE, as well as adapting digital platforms to vocational education to equip learners with practical, job-ready skills. Therefore, many potential research issues of DELE are raised, including, but not limited to, the following:

(1) Equity and access in digital education: Focuses on ensuring DELE systems provide access to quality education for all students, particularly those in underprivileged areas. The research identifies socio-economic, geographic, and cultural barriers to adopting DELE and seeks strategies to improve digital infrastructure, inclusivity, and accessibility, ensuring equitable educational opportunities.

(2) Interdisciplinary collaboration in DELE: Emphasizes collaboration between educators, engineers, and data scientists to develop effective learning systems. This research promotes knowledge sharing across disciplines to design DELE technologies that address both pedagogical and technological needs, fostering partnerships that enhance the scalability and impact of DELE.

(3) Technological pedagogy integration: Focuses on combining technological advancements with pedagogical practices in scalable DELE systems. The research explores aligning emerging technologies (AI, AR, VR) with educational theories and to explore precision education and adaptive models, ensuring that technology enhances pedagogy while addressing deployment challenges.

(4) Teacher professional development for DELE: Investigates how to equip educators with the necessary skills to implement DELE systems. The research focuses on designing professional development programs that support teachers in integrating digital tools into their classrooms, enhancing teaching efficacy and addressing challenges in diverse learning environments.

(5) Enhancing vocational education through DELE: Explores how DELE systems can be adapted for vocational education to provide job-ready skills. This research examines the use of digital simulations, AR/VR, and AI-driven assessments to replicate hands-on tasks and align DELE with industry demands, ensuring vocational learners are prepared for the workforce.

Conclusions

The field of DELE seeks contributions that advance both theoretical frameworks and practical applications to enhance digital learning systems, grounded in the systematic principles of the learning engineering approach. On the theoretical side, researchers are encouraged to explore new models and approaches that integrate pedagogy, data analytics, and technology to create optimized learning environments. The learning engineering approach emphasizes the iterative process of design, testing, and refinement, ensuring that educational technologies are not only theoretically sound but also adaptable to diverse learning contexts. This includes developing theories around adaptive learning, AI-driven personalization, and data-informed decision-making that can continuously improve educational outcomes. Practically, the field aims to foster innovations in the design, implementation, and evaluation of technology-enhanced learning environments, where learning engineering principles guide the creation of solutions that respond dynamically to learner needs. Contributions that apply these principles to tackle real-world challenges—such as increasing access to education, supporting diverse learners, and integrating robust digital infrastructures—are highly valued.

The journal will benefit a wide range of stakeholders, including educators, who can apply these insights to improve classroom instruction; researchers, who will find a rich platform for advancing knowledge in educational technologies; policy makers, who can base decisions on data-driven findings to improve education systems; learning technologists, who will be guided by theoretical and practical frameworks for building more effective digital tools; and students, who will directly experience more personalized and impactful learning environments. Furthermore, addressing the ethical, social, and policy implications of advanced technologies through the lens of learning engineering is critical for ensuring that these systems are effective, equitable, and sustainable. By advancing both theory and practice with a learning engineering foundation, the DELE field can drive meaningful improvements in the way digital technologies are designed, implemented, and used to enhance teaching and learning globally.

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