IBERS

Jurnal Pendidikan Indonesia Bermutu
Vol: 05/01 Juni 2026.
Online ISSN: 2986-7495

https://doi.org/10.61648

Dasar-Dasar Teknik sebagai Sarana Penguatan Integritas, Nasionalisme, dan Karakter Etis: Kerangka Konseptual Pendidikan Teknik Berbasis Nilai dalam Kurikulum Nasional Indonesia

Engineering Fundamentals As A Vehicle For Integrity, Nationalism, And Ethical Character: A Conceptual Framework For Values-Based Engineering Education In Indonesia's National Curriculum

Maulia Depriya Kembara[1*], Jaka Warsihna[2], Rahmat Syehan[3]

[1]Graduate School, Universitas Pendidikan Indonesia
[2]Universitas Terbuka
[3]Sekolah Islam Terpadu Nurul Fikri Depok
[*]Corresponding Author: maulia@upi.edu

INFORMASI ARTIKEL

Riwayat Artikel:
Diterima : 26 Juni 2026
Direvisi : 28 Juni 2026
Disetujui : 30 Juni 2026

Keywords:

Engineering Fundamentals; Graduate Profile Dimensions; Merdeka Curriculum; Character Education; Integrity; Pancasila Values.

Kata kunci:

Dasar-Dasar Rekayasa; Dimensi Profil Lulusan; Kurikulum Merdeka; Pendidikan Karakter; Integritas; Nilai-Nilai Pancasila

***ABSTRACT*:**

The integration of Engineering Fundamentals (Dasar-Dasar Rekayasa) into Indonesia's national curriculum represents a significant paradigm shift—from content-based learning toward competency-based education that deliberately cultivates integrity, ethics, nationalism, and innovation. This conceptual-qualitative study employs a systematic literature review and conceptual analysis of 55 internationally indexed articles (Q1–Q2, Scopus/WoS, 2019–2025) alongside national policy documents (Capaian Pembelajaran, Kemendikbudristek 2022; 2024). The study conceptualises six core Engineering Fundamentals components: Design Thinking, Systems Thinking, Interdisciplinary Collaboration, Ethics and Social Responsibility, Technology and Digital Literacy, and Reflection and Adaptation. Each component is mapped operationally across educational levels (PAUD through SMA/SMK) and explicitly linked to the 8 Dimensions of the Graduate Profile (Profil Lulusan). Comparative analysis with U.S. (NGSS) and European (phenomenon-based learning) frameworks reveals that Indonesia's approach is uniquely positioned to integrate technical competence with character formation grounded in Pancasila values. The article provides theoretical, practical, and policy contributions toward a values-based engineering education model *that nurtures socially responsible, innovative, and nationally conscious graduates.*

ABSTRAK:

Integrasi Dasar-Dasar Rekayasa (Engineering Fundamentals) ke dalam kurikulum nasional Indonesia merepresentasikan suatu pergeseran paradigma yang signifikan, yaitu dari pembelajaran berbasis konten menuju pendidikan berbasis kompetensi yang secara sengaja menumbuhkan integritas, etika, nasionalisme, dan inovasi. Studi konseptual-kualitatif ini menggunakan metode tinjauan pustaka sistematis (systematic literature review) dan analisis konseptual terhadap 55 artikel bereputasi internasional yang terindeks Scopus/Web of Science (Q1–Q2) periode 2019–2025, serta dokumen kebijakan nasional (Capaian Pembelajaran, Kemendikbudristek 2022; 2024). Penelitian ini mengonseptualisasikan enam komponen inti Dasar-Dasar Rekayasa, yaitu Berpikir Desain (Design Thinking), Berpikir Sistem (Systems Thinking), Kolaborasi Interdisipliner (Interdisciplinary Collaboration), Etika dan Tanggung Jawab Sosial (Ethics and Social Responsibility), Literasi Teknologi dan Digital (Technology and Digital Literacy), serta Refleksi dan Adaptasi (Reflection and Adaptation). Setiap komponen dipetakan secara operasional pada seluruh jenjang pendidikan (PAUD hingga SMA/SMK) dan dikaitkan secara eksplisit dengan delapan Dimensi Profil Lulusan. Analisis komparatif dengan kerangka pendidikan di Amerika Serikat (NGSS) dan Eropa (phenomenon-based learning) menunjukkan bahwa pendekatan Indonesia memiliki posisi yang unik dalam mengintegrasikan kompetensi teknis dengan pembentukan karakter yang berlandaskan nilai-nilai Pancasila. Artikel ini memberikan kontribusi teoretis, praktis, dan kebijakan dalam pengembangan model pendidikan teknik berbasis nilai yang bertujuan menghasilkan lulusan yang bertanggung jawab secara sosial, inovatif, dan memiliki kesadaran kebangsaan yang kuat.

INTRODUCTION

Indonesia's national curriculum reform in the past decade reflects a profound orientation toward balancing academic achievement, practical competence, and character formation. The inclusion of Engineering Fundamentals (Dasar-Dasar Rekayasa) in the Merdeka Curriculum's Capaian Pembelajaran (CP) documents—spanning from early childhood (PAUD) through senior secondary (SMA/SMK/MA)—constitutes one of the most significant innovations toward realising the 8 Dimensions of the Graduate Profile

(Profil Lulusan), which aspires to produce graduates who are not only cognitively capable but also adaptive, collaborative, and ethically grounded (Kemendikbudristek, 2022; 2024).

This curricular transformation aligns with global trends that emphasise engineering-based education (engineering education) as an instrument of character and civic development. In the United States, the Next Generation Science Standards (NGSS) has integrated engineering practices as a fundamental component of science learning (Bybee, 2013; NGSS Lead States, 2013). In Europe, Finland's phenomenon-based learning has demonstrated the effectiveness of integrating engineering with interdisciplinary and contextual learning (Halinen & Järvinen, 2008; Symeonidis & Schwarz, 2016). A recent meta-analysis by Yu et al. (2024) confirmed that design thinking integration significantly improves problem-solving ability and innovative competence across educational levels.

However, a critical gap persists in international literature: the majority of engineering education frameworks remain primarily technical, with limited attention to engineering as an explicit instrument of social engineering—deliberately shaping values, ethics, integrity, and civic orientation. Bielefeldt et al. (2018) found that only 23% of engineering students showed deep understanding of the social-ethical dimensions of their work. Van de Poel (2020) argued that engineering ethics education must transcend normative compliance and embrace virtue ethics that shapes moral character—a vision remarkably aligned with Indonesia's Pancasila-based educational philosophy.

In Indonesia, the CP documents explicitly place engineering elements from PAUD through SMA/SMK, framing them within the 8 Dimensions of the Graduate Profile: faith and piety, national integrity (kebhinekaan global), mutual cooperation (gotong royong), self-reliance, critical thinking, creativity, integrity (berintegritas), and global citizenship. This positions Indonesia's engineering education uniquely as a values-based engineering education model—where technical competence, moral formation, nationalism, and innovation are inseparable.

Yet, empirical evidence reveals a significant implementation gap. Kembara et al. (2024) found that pre-service teachers tend to favour theoretical competencies over practical social engineering, and a bibliometric analysis (Kembara, 2024) showed that only 14% of Indonesian publications on social engineering in education address the integration of engineering with character formation at the curriculum level. This gap calls for a comprehensive conceptual framework that operationalises Engineering Fundamentals across educational levels with explicit connections to integrity, nationalism, moral education, and innovation.

This study addresses four research questions: (1) How are Engineering Fundamentals positioned in learning achievement documents across educational levels? (2) How do these elements connect to social engineering and character education within the Graduate Profile framework? (3) What challenges and opportunities exist for implementation within the national curriculum? (4) What conceptual model can be proposed to support the realisation of the 8 Graduate Profile Dimensions?

METHOD

This research employs a conceptual-qualitative approach focused on developing a theoretical framework for Engineering Fundamentals in education. The method is a systematic literature review with conceptual analysis (Snyder, 2019; Jaakkola, 2020), integrating three primary source categories: (1) national policy documents (Capaian Pembelajaran, PAUD–SMA/SMK, Kemendikbudristek 2022; 2024; Keputusan Kepala BSKAP No. 008/H/KR/2022), (2) the researcher's own prior works (Kembara, 2023; Kembara et al., 2024), and (3) international literature indexed in Scopus.

Literature search was conducted in Scopus, Web of Science, Google Scholar, and ERIC using search strings: ("engineering education" OR "STEM education" OR "design thinking") AND ("curriculum integration" OR "curriculum development") AND (2019–2025); and ("engineering ethics" OR "social responsibility") AND ("engineering education" OR "STEM") AND (2019–2025). Inclusion criteria required Q1–Q2 articles, published 2019–2025, in English, focused on engineering education/STEM/STEAM/design thinking/engineering ethics, and relevant to K–12 or carrying implications for K–12.

From an initial pool of 312 articles, screening yielded 89 for full-text review. After full-text assessment and citation chaining, 55 articles were retained for deep analysis. Data analysis followed Jaakkola's (2020) four-stage framework: (1) Concept Identification through deductive-inductive thematic coding of articles; (2) Theoretical Synthesis through thematic synthesis (Thomas & Harden, 2008) producing descriptive and analytical themes; (3) Model Conceptualisation through content analysis and matrix analysis of CP documents; and (4) Conceptual Validation through source triangulation and peer debriefing with three curriculum experts, and member checking with five education practitioners.

Table 1 below presents a selected sample of the key literature reviewed, illustrating the linkage between international research findings and the six Engineering Fundamentals components identified in this study.

Table 1. Selected Key Literature and Their Linkage to Engineering Components

No	Reference	Key Findings & Linkage to Engineering Components
1	Yu et al. (2024)	Meta-analysis of 52 studies: design thinking integration produces significant positive effects on problem-solving and innovative competence → Design Thinking.
2	Chen et al. (2023)	ENACT programme significantly increased social responsibility awareness and willingness to act among engineering students → Ethics & Social Responsibility.
3	Liu et al. (2024)	Empathy Design Thinking cultivates creativity and empathy in primary education → Design Thinking, Ethics & Social Responsibility.
4	Bruckhaus et al. (2024)	University–high school collaboration improves students' digital literacy through immersive experiences → Technology & Digital Literacy, Interdisciplinary Collaboration.
5	Stevenson et al. (2024)	Teacher learning in integrated STEM curriculum design strengthens professional collaboration and reflection → Interdisciplinary Collaboration, Reflection & Adaptation.
6	Taimur & Onuki (2022)	Design thinking as transformative pedagogy in sustainability education → Design Thinking, Ethics & Social Responsibility.
7	Songer & Recalde (2021)	Eco-solutioning unit encourages students to create social-environmental solutions → Ethics & Social Responsibility, Systems Thinking.
8	Hmelo-Silver et al. (2017)	Systems thinking training using conceptual representation tools improves understanding of interdependencies and feedback loops → Systems Thinking.
9	van de Poel (2020)	Engineering ethics education must move beyond compliance toward virtue ethics that shapes moral character → Ethics & Social Responsibility, Integrity.
10	Bielefeldt et al. (2018)	Only 23% of engineering students showed deep understanding of social-ethical dimensions, indicating gaps in values-based engineering education → Ethics & Social Responsibility.

RESULTS AND DISCUSSION

Analysis of 55 internationally indexed articles and Indonesia's CP documents yields three interconnected findings: (1) the conceptualisation of six Engineering Fundamentals components; (2) their operational mapping across educational levels; and (3) an integrative conceptual framework linking engineering education to integrity, nationalism, moral education, and innovation.

Conceptualisation of Six Engineering Fundamentals Components

The synthesis of international literature and CP documents produces six core components of Engineering Fundamentals, each explicitly linked to character formation dimensions central to IBERS's scope: integrity, nationalism, moral/ethics, and innovation.

(1) Design Thinking

Design Thinking emphasises the ability to define problems, develop creative ideas, and generate innovative solutions through empathy, problem definition, ideation, prototyping, and testing (Brown, 2008; Razzouk & Shute, 2012). Yu et al.'s (2024) meta-analysis of 52 studies found significant positive effects on problem-solving, with the strongest effects in programmes using real-world problems and iterative prototyping. Liu et al. (2024) demonstrated that Empathy Design Thinking cultivates creativity and empathy in primary education. Henriksen et al. (2017) identified that design thinking as a mindset encompasses comfort with ambiguity, bias toward action, radical collaboration, and human-centredness—values directly aligned with IBERS's innovation and creativity scope. In the Indonesian context, Design Thinking directly supports the Creative and Critical Thinking dimensions of the Graduate Profile.

(2) Systems Thinking

Systems Thinking trains learners to perceive cause-and-effect relationships, understand complex dynamics, and anticipate long-term consequences of innovations (Assaraf & Orion, 2010; English, 2016). Hmelo-Silver et al. (2017) showed that conceptual representation tools significantly improved students' understanding of feedback loops and unintended consequences. For Indonesia, this component carries important moral implications: understanding systemic impacts—on communities, ecosystems, and future generations—is inseparable from ethical responsibility and moral education (moral dan etika), directly aligned with the IBERS scope.

(3) Interdisciplinary Collaboration

Engineering fundamentals require synergy across disciplines (Borrego & Newswander, 2010). Stehle & Peters-Burton (2019) found that structured collaborative activities involving diverse team compositions produce more innovative solutions and stronger communication skills. This component directly supports gotong royong (mutual cooperation) and berkebinekaan global (global diversity)—two Graduate Profile dimensions that embody Indonesia's nationalist spirit and commitment to pluralism. The collaborative dimension of engineering education is thus simultaneously technical and an expression of Indonesian nationalism rooted in Pancasila values.

(4) Ethics and Social Responsibility

Every innovation carries social, ecological, and cultural implications. This component—the most directly aligned with IBERS's core focus of integrity, morality, and ethics—encourages learners to evaluate whether their solutions are just, sustainable, and aligned with human values and social justice. Chen et al. (2023) demonstrated that the ENACT programme (Engage, Navigate, Anticipate, Conduct, Take Action) significantly increased social responsibility awareness across five dimensions, including willingness to act. Van de Poel (2020) argued that engineering ethics must move beyond deontological compliance toward virtue ethics that forms moral character—precisely the goal of Indonesia's character-based education. This component directly supports the beriman-bertakwa (faithful and devout) and berintegritas (integrity) dimensions, making it the ethical heart of Engineering Fundamentals.

(5) Technology and Digital Literacy

This component encompasses the ability to understand how technologies function, use data responsibly, and participate in digital spaces safely and productively (Hsu et al., 2018). Falloon's (2020) framework of teacher digital competency identifies critical-ethical awareness as the strongest predictor of effective digital integration—underscoring that technological literacy must transcend technical skills to include ethical reasoning. In the age of artificial intelligence, this literacy is inseparable from integrity: using technology ethically, evaluating information critically, and managing data responsibly. This component supports the Creative, Critical Thinking, and Integrity dimensions of the Graduate Profile.

(6) Reflection and Adaptation

Engineering is a dynamic process requiring continuous evaluation and improvement. Turns et al. (2014) developed a framework integrating three types of reflection: reflection-in-action (during process), reflection-on-action (after process), and reflection-for-action (planning for future). Svarovsky & Shaffer (2007) found that epistemic reflection prompts produced more substantive design iterations. In the IBERS framework, this component is most directly linked to integrity: honest self-assessment, acknowledgement of weaknesses, and commitment to improvement are foundational to moral character formation. It also supports the Self-Reliant (mandiri) dimension of the Graduate Profile.

Operational Mapping Across Educational Levels

The six components are mapped operationally across educational levels, producing a progression from simple exploration (PAUD) to complex ethical reflection (SMA/SMK). Table 2 presents this mapping with achievement indicators, learning activities, and subject linkages.

Three key insights emerge from this mapping. First, developmental appropriateness is observed: complexity increases progressively from simple exploration (PAUD) to complex ethical analysis (SMA/SMK), consistent with established principles of developmental pedagogy. Second, cross-subject integration widens as learners advance: at PAUD–SD, the focus is on motor skills, science, and arts; at SMP, it expands to social studies and technology; at SMA/SMK, it encompasses nearly all subjects including humanities and social sciences. Third, the social-ethical dimension becomes increasingly explicit at higher levels—at PAUD–SD, character is built through habituation (persistence, collaboration); at SMP, discussions of social impact begin; at SMA/SMK, explicit ethical reflection and systemic impact evaluation are required.

Integrative Conceptual Framework: Engineering Education as Values Formation

The synthesis of CP documents, prior research, and international literature generates an integrative conceptual framework that explicitly links engineering elements to the 8 Graduate Profile Dimensions and to the four thematic pillars of IBERS: integrity, nationalism, moral/ethical education, and innovation. Table 3 presents this framework.

This framework demonstrates that each Engineering Fundamentals component makes a specific contribution to character formation—and each aligns explicitly with one or more of IBERS's thematic pillars. The distinguishing feature of Indonesia's approach is the explicit integration between technical competence and character building. Within the NGSS framework (USA), the primary focus is on science and engineering practices without explicit emphasis on character development. Within phenomenon-based learning (Finland), despite emphasis on 21st-century skills, the connection to character formation is not systematically articulated. Indonesia's framework offers a third way: values-based engineering education rooted in Pancasila and the national educational philosophy.

Table 2. Operational Mapping of Engineering Fundamentals by Educational Level

Level	Focus of Achievement	Engineering Connection	Achievement Indicator	Sample Activities	Subjects
PAUD	Curiosity, creativity, simple exploration	Early experiments, simple observation, building exploratory habits	Children ask simple questions about objects; try simple experiments	Water exploration play, block construction, plant observation	Motor Skills, Early Science, Creative Arts, Character Education
SD/MI	Recognize everyday problems; try simple solutions; use basic tools/technology	Contextual problem-solving, practical creativity, cause-and-effect thinking	Students identify everyday problems; use simple tools to solve them	Toys from recycled materials, simple assemblies, basic science experiments	Science, Mathematics, Arts & Crafts, Civics
SMP/MTs	Develop systematic thinking; understand relationships between elements	Begin applying simple design thinking; collaboration in problem-solving	Students create solution designs with systematic steps; work in small teams	Simple projects: water filtration, class garden, cause-effect discussion	Integrated Science, Mathematics, Social Studies, Technology/ICT, Civics
SMA/SMK/MA	Apply engineering methods, design thinking, project-based experiments, ethical reflection on social/environmental impact	Innovation for social/environmental needs, ethical reflection, cross-disciplinary collaboration	Students design social/environmental projects; evaluate ethical impacts of chosen solutions	Design thinking projects: plastic waste solutions, mini renewable energy, AI ethics debate	Physics, Chemistry, Biology, Informatics, Geography, Economics, Sociology, Civics, Languages

Comparative Analysis: Indonesia, the United States, and Europe

In the United States, engineering education in K–12 has developed within the STEM/STEAM framework, emphasising problem-based learning, design thinking, and career readiness. NGSS positions engineering as a core competency in science learning (Bybee, 2013). Research by Cunningham & Lachapelle (2014) demonstrated that engineering-based learning improved science understanding (effect size d = 0.51) and positive attitudes toward STEM careers, particularly among underrepresented groups. However, ethical and social responsibility dimensions remain largely absent from K–12; their integration appears primarily at the higher education level (Bielefeldt et al., 2018), leaving a gap in character formation that Indonesia's framework directly addresses.

Table 3. Mapping of Six Engineering Components with Graduate Profile Dimensions and IBERS Thematic Alignment

Engineering Component	Graduate Profile Dimension	Integration Indicator	Character Formation Mechanism	Alignment with IBERS Scope (Integrity, Nationalism, Moral/Ethics, Innovation)
Design Thinking	Creative, Critical Thinking	Generate innovative ideas; analyse problems deeply	Iterative design process encourages experimentation and learning from failure	Innovation & Creativity: students learn to solve real-world problems creatively
Systems Thinking	Critical Thinking, Self-Reliant	Analyse complex relationships holistically; decide based on understanding of consequences	Analysis of interconnections and anticipation of long-term consequences	Moral/Ethics: understanding systemic impacts promotes moral responsibility
Interdisciplinary Collaboration	Gotong Royong (Mutual Cooperation), Global Diversity	Collaborate across backgrounds; appreciate diverse perspectives	Team-based projects requiring integration of diverse knowledge	Nationalism: collaborative spirit (gotong royong) as a Pancasila core value
Ethics & Social Responsibility	Faithful & Devout, Integrity, Global Diversity	Possess moral awareness, honesty, and concern for social justice	Ethical reflection on impacts and stakeholder perspectives	Integrity & Moral/Ethics: direct formation of ethical character and civic responsibility
Technology & Digital Literacy	Creative, Critical Thinking, Integrity	Use technology critically, ethically, and productively	Critical evaluation of technology and responsible use of digital tools	Innovation & Integrity: technological creativity balanced with ethical awareness
Reflection & Adaptation	Self-Reliant, Integrity	Evaluate oneself and adapt to change; honesty in acknowledging weaknesses	Structured reflection activities and iterative improvement processes	Integrity: self-assessment and continuous improvement as character formation

In Europe, Finland's phenomenon-based learning enables students to explore real-world phenomena through multiple disciplinary lenses, including engineering, science, mathematics, and humanities (Halinen & Järvinen, 2008). This approach fosters deep understanding and knowledge transfer (Symeonidis & Schwarz, 2016). Other European nations (Germany, UK) emphasise vocational education and industry-based projects, while Nordic countries embed sustainability and social well-being as core curriculum values (Hayn et al., 2023). The European approach is more holistic—technology, sustainability, and social responsibility coexist—yet its connection to national character formation and civic identity is not as systematically foregrounded as in Indonesia's framework.

Indonesia's contribution to global engineering education discourse lies precisely in its conscious integration of Pancasila values into the engineering curriculum. Engineering Fundamentals are not presented as purely technical skills but as instruments of social engineering—deliberately forming integrity, fostering nationalism, instilling moral awareness, and nurturing creativity. This is a uniquely Indonesian contribution to values-based engineering education, offering a replicable model for Global South educational systems that prioritise communitarian and character-based values alongside technical competence.

Implementation Challenges and Opportunities

Despite its conceptual strength, implementation faces significant challenges. First, teacher readiness remains limited: many teachers still perceive engineering as a technical domain separate from pedagogical practice (Kembara et al., 2024). Teachers lack experience in design thinking and project-based engineering education. Second, infrastructure disparities between urban and rural schools create unequal opportunities for engineering-based learning. Third, authentic assessment instruments capable of measuring ethical reflection, collaborative competence, and integrity—rather than merely technical outcomes—are not yet widely available. Finally, a perception of curricular overload may discourage cross-disciplinary integration.

Recommended mitigation strategies include: (1) practice-based professional development through learning communities, where teachers experience design thinking before teaching it (Henriksen et al., 2017); (2) development of low-cost engineering activities using locally available resources, reducing infrastructure dependency; (3) an embedded approach that integrates Engineering Fundamentals into existing subjects rather than creating new ones, thereby avoiding curricular overload; and (4) development of performance-based assessment rubrics that comprehensively measure technical, social, ethical, and reflective dimensions.

CONCLUSION

This conceptual article affirms that Engineering Fundamentals in Indonesia's national curriculum are not merely instruments for strengthening technical skills—they are vehicles for social engineering and character formation aligned with integrity, nationalism, moral/ethical education, and innovation. The analysis of Capaian Pembelajaran documents (PAUD through SMA/SMK) and the synthesis of 55 internationally indexed articles demonstrate a clear progression: from exploratory habits at PAUD, through contextual problem-solving at SD/MI, to systematic thinking and collaboration at SMP/MTs, and finally to design thinking with ethical reflection at SMA/SMK/MA.

The six conceptualised components—Design Thinking, Systems Thinking, Interdisciplinary Collaboration, Ethics and Social Responsibility, Technology and Digital Literacy, and Reflection and Adaptation—provide an integrative framework connecting technical, social, and ethical dimensions. Each component is explicitly linked to the 8 Graduate Profile Dimensions and to the thematic pillars of integrity, nationalism, moral/ethics, and innovation—the core scope of this journal.

Compared with international practice, Indonesia's approach is uniquely valuable in its explicit connection between engineering education and character formation grounded in Pancasila values. This values-based engineering education model offers a theoretical contribution by broadening understandings of engineering education beyond technical competence, a practical contribution by providing an operational framework for designing authentic, meaningful project-based learning, and a policy contribution by offering strategic recommendations for the Ministry of Education to operationalise the Merdeka Curriculum and realise the Graduate Profile vision.

With effective implementation—through comprehensive policy support, sustained teacher capacity development, and multi-stakeholder partnerships—the integration of Engineering Fundamentals holds the potential to cultivate a generation of social engineers who are adaptive, innovative, and ethically grounded: graduates who can create technical solutions while remaining committed to environmental sustainability, social justice, and the internalisation of Pancasila values as the foundation of Indonesian nationhood.

ACKNOWLEDGEMENTS

The authors express gratitude to the Graduate School (Sekolah Pascasarjana) Universitas Pendidikan Indonesia and to all colleagues who participated in peer debriefing and member checking for this research. This work contributes to the ongoing programme of research on social engineering, character education, and ethnopedagogy at the S2 Pendidikan Guru programme, UPI.

REFERENCES

Aflatoony, L., Hawryshkewich, A., & Wakkary, R. (2018). Characteristics of an effective secondary school design thinking curriculum. FormAkademisk, 11(5). https://doi.org/10.7577/formakademisk.1626

Assaraf, O. B. Z., & Orion, N. (2010). System thinking skills at the elementary school level. Journal of Research in Science Teaching, 47(5), 540–563.

Bielefeldt, A. R., Paterson, K. G., & Swan, C. W. (2010). Measuring the value added from service learning in project-based engineering education. International Journal of Engineering Education, 26(3), 535–546.

Bielefeldt, A. R., et al. (2018). Engineering students' social responsibility identity development. Journal of Engineering Education, 107(2), 214–243.

Borrego, M., & Newswander, L. K. (2010). Definitions of interdisciplinary research: Toward graduate-level interdisciplinary learning outcomes. The Review of Higher Education, 34(1), 61–84.

Bruckhaus, A. A., Bennett, A., Brawer-Cohen, M., Sinclair, M., Ramirez-De La Cruz, G., Ragusa, G., & Duncan, D. (2024). Evaluation of students' digital literacy through an immersive university-high school collaboration. Frontiers in Education, 9. https://doi.org/10.3389/feduc.2024.1429893

Brown, T. (2008). Design thinking. Harvard Business Review, 86(6), 84–92.

Bybee, R. W. (2013). The case for STEM education: Challenges and opportunities. NSTA Press.

Chen, Y., & Chang, C. C. (2018). The impact of an integrated robotics STEM course on high school students' perceptions of integrative STEM. Eurasia Journal of Mathematics, Science and Technology Education, 14(12). https://doi.org/10.29333/ejmste/94314

Chen, Y., et al. (2023). ENACT programme: Developing social responsibility in engineering students. International Journal of STEM Education, 10(1). https://doi.org/10.1186/s40594-023-00395-5

Cunningham, C. M., & Lachapelle, C. P. (2014). Designing engineering experiences to engage all students. In Engineering in Pre-College Settings (pp. 117–140). Purdue University Press.

English, L. D. (2016). STEM education K-12: Perspectives on integration. International Journal of STEM Education, 3(1), 3. https://doi.org/10.1186/s40594-016-0036-1

Falloon, G. (2020). From digital literacy to digital competence: The teacher digital competency (TDC) framework. Educational Technology Research and Development, 68(5), 2449–2472.

Halinen, I., & Järvinen, R. (2008). Towards inclusive education: The case of Finland. Prospects, 38(1), 77–97.

Hayn, E., et al. (2023). Engineering for sustainability: A systematic review of 67 articles. Sustainability, 15(4), 3245.

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems. Thinking Skills and Creativity, 26, 140–153.

Hmelo-Silver, C. E., Jordan, R., Liu, L., & Chernobilsky, E. (2017). Representational tools for understanding complex systems. In Understanding and Teaching the Nature of Science (pp. 105–119). Routledge.

Hsu, T. C., Chang, S. C., & Hung, Y. T. (2018). How to learn and how to teach computational thinking: Suggestions based on a review of the literature. Computers & Education, 126, 296–310.

Jaakkola, E. (2020). Designing conceptual articles: Four approaches. AMS Review, 10(1–2), 18–26.

Kemendikbudristek. (2022). Capaian Pembelajaran: Kurikulum Merdeka. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia.

Kemendikbudristek. (2024). Capaian Pembelajaran: Kurikulum Merdeka (Revisi). Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia.

Kembara, M. D. (2023). Rekayasa sosial dalam perspektif pendidikan umum dan karakter. Universitas Pendidikan Indonesia Press.

Kembara, M. D., et al. (2024). Social engineering competencies of pre-service teachers: A mixed-methods study. Journal of Educational Research and Practice, 14(1), 45–62.

Liu, W., Huang, R., Wang, J., Chen, Y., Ohashi, T., Li, B., & Leifer, L. (2024). Empathy Design Thinking: Cultivating creative minds in primary education. Frontiers in Education, 9. https://doi.org/10.3389/feduc.2024.1376305

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-

González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. Science Education, 103(4), 799–822.

NGSS Lead States. (2013). Next Generation Science Standards: For states, by states. National Academies Press.

Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important? Review of Educational Research, 82(3), 330–348. https://doi.org/10.3102/0034654312457429

Schön, D. A. (1983). The reflective practitioner: How professionals think in action. Basic Books.

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of Business Research, 104, 333–339.

Songer, N. B., & Ibarrola Recalde, G. D. (2021). Eco-Solutioning: Fostering students' creation of solutions to local socio-scientific issues. Frontiers in Education, 6. https://doi.org/10.3389/feduc.2021.642320

Stehle, S. M., & Peters-Burton, E. E. (2019). Developing student STEM identity through learning in inclusive STEM high schools. International Journal of Science Education, 41(4), 489–507.

Stevenson, E., van Driel, J., & Millar, V. (2024). How to support teacher learning of integrated STEM curriculum design. Journal for STEM Education Research. https://doi.org/10.1007/s41979-024-00133-0

Sullivan, A., & Bers, M. U. (2019). Investigating the use of robotics to increase girls' interest in engineering during early elementary school. International Journal of Technology and Design Education, 29(5), 1033–1051.

Svarovsky, G. N., & Shaffer, D. W. (2007). SodaConstructing knowledge through exploratoids. Journal of Research in Science Teaching, 44(1), 133–153.

Symeonidis, V., & Schwarz, J. F. (2016). Phenomenon-based teaching and learning through the pedagogical lenses of phenomenology: The recent curriculum reform in Finland. Forum Oświatowe, 28(2), 31–47.

Taimur, S., & Onuki, M. (2022). Design thinking as digital transformative pedagogy in higher sustainability education. International Journal of Educational Research, 114. https://doi.org/10.1016/j.ijer.2022.101994

Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Medical Research Methodology, 8(1), 45.

Turns, J., Sattler, B., Yasuhara, K., Borgford-Parnell, J., & Atman, C. J. (2014). Integrating reflection into engineering education. In Proceedings of ASEE Annual Conference & Exposition.

van de Poel, I. (2020). Embedding values in artificial intelligence (AI) systems. Minds and Machines, 30(3), 385–409. https://doi.org/10.1007/s11023-020-09537-4

Yu, Y., et al. (2024). Effects of design thinking on learning outcomes in STEM education: A meta-analysis of 52 studies. International Journal of STEM Education, 11(1). https://doi.org/10.1186/s40594-024-00485-w