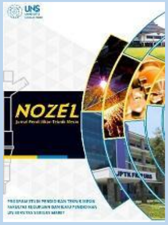

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ALIGNING MICRO-CREDENTIALS WITH THE INDONESIAN NATIONAL COMPETENCY STANDARDS (SKKNI) AND QUALIFICATIONS FRAMEWORK (KKNI) FOR MECHANICAL ENGINEERING EDUCATION: A SYSTEMATIC REVIEW

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Abstract

Micro-credentials have emerged as a global instrument for recognising discrete competences, yet their uptake in Indonesian vocational education remains disconnected from the national competency architecture built on SKKNI and KKNI. This study maps the mechanisms through which micro-credentials are aligned with qualifications frameworks and competency standards, and synthesises an alignment pathway for mechanical engineering education. A systematic literature review following PRISMA 2020 was conducted on two Scopus strands: an international strand on credential-framework alignment (n = 32) and a national strand on SKKNI/KKNI implementation (n = 15). After deduplication and screening, 37 studies were synthesised using best-fit framework synthesis. The international corpus reveals five alignment mechanisms: learning-outcome anchoring, stackability and articulation, industry co-design, verifiable recognition infrastructure, and educator capability credentialing. The national corpus shows that SKKNI/KKNI research concentrates on curriculum referencing, competency testing, and teacher standards, but contains no study connecting micro-credentials to either instrument, and none in mechanical engineering. The article contributes a four-stage SKKNI-micro-credential alignment pathway comprising decomposition, outcome formulation, verifiable credentialing, and KKNI levelling as a design basis for micro-credential development in Indonesian vocational mechanical engineering programmes.

Keywords: *micro-credentials, SKKNI, KKNI, mechanical engineering education, systematic literature review*

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INTRODUCTION

The velocity of technological change in manufacturing has outpaced the renewal cycle of formal vocational qualifications. Computer numerical control (CNC) machining, industrial automation, additive manufacturing, and data-driven maintenance now redefine the competence profile of machine operators, technicians, and vocational teachers within timeframes far shorter than a diploma or degree programme can accommodate. In response, micro-credentials (short, assessed, and portable certifications of discrete competences, frequently represented as digital badges) have moved from the margins of educational innovation to the centre of global policy conversations. Salmon (2023) identifies flexibility and employability as the two dominant drivers of this global push, as universities and training providers seek credential formats that can be earned quickly, stacked progressively, and read directly by employers. In engineering and manufacturing education specifically, micro-credentials have been positioned as vehicles for stackable technician pathways (Kinney, Sergeyev, Kuhl, & Highum, 2016), for continuing engineering education across the professional lifespan (Kimmel, Rockland, Carpinelli, & Spak, 2022; Smith & Kálmán, 2023), and for recognising laboratory and workshop competences that traditional transcripts render invisible (Gregg, Park, Fenton, Lang, & Handley, 2022).

The credibility of any credential, however, ultimately rests on what it references. International scholarship is increasingly explicit that micro-credentials acquire currency only when they are anchored to recognised qualifications frameworks, competency standards, or skills taxonomies (Ward et al., 2021; Catenazzi, Sommaruga, De Angelis, & Caboni, 2025; Stankovski, 2025). A badge that certifies “CNC turning” means little unless the issuing body can show which standardised units of competence it covers, how the evidence was assessed, and where the badge sits within a levelled qualification architecture. Absent such anchoring, micro-credentials risk devolving into unregulated market signals, a risk sharpened by critiques of credential proliferation and the stratifying potential of short-cycle awards (Giani & Fox, 2017; Salmon, 2023).

Indonesia possesses precisely the anchoring architecture that this international literature calls for. The Indonesian National Qualifications Framework (Kerangka

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Kualifikasi Nasional Indonesia, KKNI), established through Presidential Regulation Number 8 of 2012, defines nine qualification levels that equate learning outcomes acquired through formal education, training, work experience, and self-directed learning (Peraturan Presiden Republik Indonesia Nomor 8 Tahun 2012, 2012). Beneath it, the Indonesian National Work Competency Standards (Standar Kompetensi Kerja Nasional Indonesia, SKKNI) specify units of competence, each decomposed into elements and performance criteria, for occupational fields including machining, welding, maintenance, and manufacturing engineering, under the national work-competency standardisation system (Peraturan Menteri Ketenagakerjaan Republik Indonesia Nomor 2 Tahun 2016, 2016). Together with competency certification conducted through licensed professional certification bodies (Lembaga Sertifikasi Profesi, LSP) under the National Professional Certification Authority (Badan Nasional Sertifikasi Profesi, BNSP) and the recognition of prior learning (RPL) mechanism, these instruments constitute a complete national grammar for describing, assessing, levelling, and recognising competence.

Yet the two conversations have not met. Indonesian research has operationalised SKKNI and KKNI extensively, through curriculum development referenced to competency standards (Nilasari & Dasining, 2018; Umam, Susilo, Purba, & Adityatama, 2020), KKNI descriptor development for recognition of prior learning (Zamtinah & Supriyadi, 2018), competency testing in vocational schools (Mandalika, Sukardi, & Minghat, 2018), and teacher competency standards for the digital era (Widaningsih, Maknun, Dwiyanti, Ramdanisari, & Muktiarni, 2025). Yet this literature is silent on micro-credentials. Conversely, the international micro-credential literature elaborates sophisticated alignment mechanisms while remaining, understandably, silent on Indonesian instruments. For mechanical engineering education the silence is doubly consequential: it is among the most densely standardised occupational fields in the SKKNI corpus, its laboratory- and workshop-based competences are natural candidates for badge-sized recognition, and its graduates face certification requirements that micro-credentials could scaffold rather than duplicate.

No systematic review has yet bridged these two bodies of literature. Existing reviews of micro-credentials concentrate on higher education in general, on single national systems in the Global North, or on technological infrastructure, and none addresses the Indonesian

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standards architecture or the mechanical engineering field. This article therefore contributes the first systematic mapping of international credential-standard alignment mechanisms against Indonesian SKKNI/KKNI implementation research, and synthesises from that mapping a design pathway for micro-credentials in vocational mechanical engineering education. Three research questions guide the review: (1) What mechanisms does the international literature employ to align micro-credentials with qualifications frameworks and competency standards? (2) How has Indonesian research operationalised SKKNI and KKNI in engineering and vocational competency development? (3) How can these mechanisms be synthesised into an alignment pathway for micro-credentials in Indonesian mechanical engineering education? The review is limited in scope to Scopus-indexed literature published from 2012, the year KKNI was enacted, to July 2026; the implications of this boundary are examined in the discussion.

METHOD

This study employed a systematic literature review (SLR) design reported in accordance with the PRISMA 2020 statement (Page et al., 2021). The design was selected because the research questions require transparent identification, screening, and synthesis of two bodies of evidence that have developed in parallel and must be brought into structured contact. The review proceeded through four stages: search strategy formulation, study selection, data extraction, and synthesis.

The search was executed in Scopus in July 2026 using two complementary strands, an approach necessitated by a structural feature of the evidence base: a single combined query intersecting micro-credential terminology with SKKNI/KKNI terminology returns a near-empty set, because the intersection is precisely the research gap under investigation. The international strand therefore captured studies on aligning micro-credentials, digital badges, and stackable credentials with qualifications frameworks and competency standards in vocational and engineering contexts, while the national strand captured Indonesian studies operationalising SKKNI and KKNI in engineering and vocational competency development. The full search strings are reproduced in Table 1. The international strand retrieved 32 records and the national strand retrieved 15 records, yielding 47 records in total.

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Table 1. Search strings executed in Scopus (July 2026)

Strand	Scopus search string
International (n = 32)	TITLE-ABS-KEY (("micro-credential*" OR "microcredential*" OR "digital badge*" OR "open badge*" OR "alternative credential*" OR "stackable credential*") AND ("qualification* framework*" OR "competenc* standard*" OR "occupational standard*" OR "skill* standard*" OR "competenc* framework*" OR "credential recognition" OR "recognition of prior learning" OR align* OR mapping OR articulat*) AND (vocational OR "TVET" OR "engineering education" OR "mechanical engineering" OR machining OR manufactur*)) AND PUBYEAR > 2012
National (n = 15)	TITLE-ABS-KEY (("SKKNI" OR "KKNI" OR "Indonesian Qualification* Framework" OR "national competenc* standard*") AND ("micro-credential*" OR "digital badge*" OR certification OR competenc*) AND (vocational OR engineering OR "TVET" OR "SMK")) AND (LIMIT-TO (AFFILCOUNTRY , "Indonesia"))

Selection followed predefined inclusion and exclusion criteria, summarised in Table 2. Records were eligible if they were peer-reviewed journal articles, conference papers, or book chapters published from 2012 onward that either (a) addressed the alignment of micro-credentials, digital badges, or stackable credentials with qualifications frameworks, competency standards, or skills taxonomies in vocational, engineering, or professional education (international strand), or (b) operationalised SKKNI, KKNI, or derivative national competency standards in engineering or vocational education contexts (national strand). Conference front matter, editorial reviews of proceedings, and records that mentioned neither credential-standard alignment nor SKKNI/KKNI operationalisation were excluded.

Table 2. Inclusion and exclusion criteria

Category	Criteria
Inclusion	Peer-reviewed article, conference paper, or book chapter; published 2012–July 2026; indexed in Scopus; addresses micro-credential/badge/stackable-credential alignment with frameworks, standards, or taxonomies in vocational, engineering, or professional education (international strand); or operationalises SKKNI/KKNI in engineering or vocational competency development (national strand); written in English or Indonesian.
Exclusion	Duplicate records; conference front matter and proceedings reviews without research content; records addressing neither credential-standard alignment nor SKKNI/KKNI operationalisation (e.g., general digitalisation of services); records with no extractable findings.

The selection process is summarised in Figure 1. Of the 47 identified records, three duplicate proceedings entries were removed, leaving 44 records screened on title, abstract, and keywords. Seven records were excluded at screening: two conference front-matter records containing no research content, and five records that addressed neither credential-standard alignment nor SKKNI/KKNI operationalisation. All 37 remaining records were assessed in full text and retained, comprising an international corpus of 24 studies and a national corpus of 13 studies. Given the methodological heterogeneity of the corpus, which spans qualitative case studies, design reports, survey research, and conceptual papers, no single quality-appraisal weighting was applied; instead, rigor was safeguarded through strict application of the selection criteria and through triangulation across studies during synthesis.

Data were extracted into a structured matrix recording author and year, national or institutional context, educational level, occupational field, alignment mechanism or standards instrument addressed, and principal findings. Synthesis followed the best-fit framework synthesis procedure (Carroll, Booth, & Cooper, 2011). An a priori coding frame was seeded from the two conceptually richest records in the corpus, namely the personalised learning skills taxonomy of Ward et al. (2021) and the learning-outcome-based curriculum and certification methodology of Catenazzi et al. (2025), and was then expanded inductively as the remaining records were coded, producing the five international mechanisms and four national implementation patterns reported below. In the final synthesis step, the international mechanisms were cross-mapped onto anchor points in the SKKNI/KKNI architecture evidenced by the national corpus, from which the alignment pathway answering the third research question was constructed.

RESULTS AND DISCUSSION

1. Results

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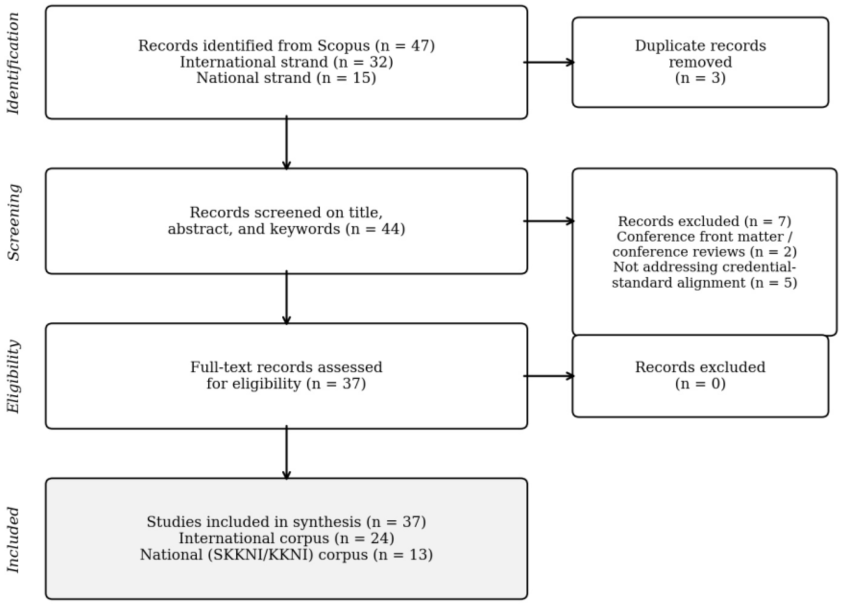

Figure 1. PRISMA 2020 flow of study identification, screening, and inclusion

a. Characteristics of the included studies

The 24 studies of the international corpus are characterised in Table 3. They span the United States, the United Kingdom, Finland, Sweden, Portugal, Spain, Malaysia, Australia, and pan-European initiatives, and are dominated by conference papers (15 of 24), with six journal articles and three book chapters. Their temporal distribution is strongly recent: 18 of the 24 studies (75%) were published between 2021 and 2026, confirming that credential-standard alignment is an accelerating research front rather than a settled field. Substantively, the corpus concentrates on engineering, manufacturing, computing, and educator development, contexts whose laboratory-based, safety-critical, and rapidly evolving competences most closely parallel those of Indonesian mechanical engineering education.

Table 3. Characteristics of the international corpus (n = 24)

No	Author (Year)	Context	Focus relevant to alignment
1	Salmon (2023)	Global higher education	Drivers of micro-credential uptake: flexibility and employability agendas
2	Wosczyna-Birch (2018)	United States, community colleges	Machining and manufacturing technology programmes linked to industry credentials and partnerships
3	Giani & Fox (2017)	United States, community colleges	Equity effects of stackable credential pathways in workforce programmes

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No	Author (Year)	Context	Focus relevant to alignment
4	Saad, Haziq Bin Abdul Jamal, & Roshidi Bin Amran (2024)	Malaysia, higher learning institutes	Institutional hurdles of micro-credential integration; blockchain-verified badges
5	Kullaslahti, Ruhalahti, & Brauer (2019)	Finland, professional development	Standardised competence frameworks supporting digital badging practice
6	Stankovski (2025)	European education frameworks	Micro-credentials for micro-competences referenced to European frameworks; blockchain recognition
7	Kimmel, Rockland, Carpinelli, & Spak (2022)	Continuing engineering education	Credentials, assessment, and content design in remote continuing education
8	Tubino & Zaidi (2026)	Australia, postgraduate	Persona-aligned assessment design for micro-credentials in emerging technologies
9	Catenazzi, Sommaruga, De Angelis, & Caboni (2025)	Europe, vocational education and training	Learning-outcome-based methodology for curriculum, delivery, and badge certification
10	Rüütmann & Läänemets (2025)	IGIP international network	Standardised prototype curricula for engineering educators' pedagogical training
11	Park, Conklin, & Sankaranarayanan (2025)	Adult and lifelong learning	Digital badges and microlearning for mastering emerging technologies
12	Khan, Qubbaj, Saenz, & Zhang (2023)	United States, cybersecurity	Embedded stackable credentials bridging two-year and four-year curricula
13	Ward et al. (2021)	United Kingdom	Personalised learning skills taxonomy for micro-credential accreditation
14	Kinney, Sergeyev, Kuhl, & Highum (2016)	United States, robotics	Stackable credential pathways through college-university partnership
15	Mugayitoglu, Borowczak, & Burrows (2021)	United States, K-12 educators	Design of a cybersecurity micro-credential for teacher professional development
16	Hayes & Rangus (2026)	European Union, tourism education	Micro-credentials within EU policy for professional practice
17	de la Torre & Wells (2014)	United States, Massachusetts	Transfer and articulation policy in tension with short-cycle workforce credentials
18	Kemcha, Alario-Hoyos, & Kloos (2025)	Spain	Agentic artificial intelligence supporting micro-credential design
19	Hutchins, Zhang, Barrett, & Israel (2025)	United States, K-12 educators	Co-design of an artificial intelligence micro-credential with and for teachers
20	Rebola, Carvalho, Marchão, Ferreira, & Castanho (2025)	Portugal, higher education	Digital learning ecosystems experienced by graduates of a micro-credential
21	Gregg, Park, Fenton, Lang, & Handley (2022)	United States, engineering students	Motivations for and perceived utility of badges earned outside class
22	Kinney, Highum, Sergeyev, & Kuhl (2018)	United States, rural industry	Mechatronics and robotics credential pathways answering industry needs

No	Author (Year)	Context	Focus relevant to alignment
23	Uusimaki (2025)	Sweden, teacher education	Piloting competence-based digital open badges (EduSTA project)
24	Smith & Kálmán (2023)	Europe, engineering education	Continuing engineering education for lifelong skills and competences

The 13 studies of the national corpus are characterised in Table 4. All are authored from Indonesian institutions and all engage SKKNI, KKNI, or derivative national competency standards; ten are conference papers and three are journal articles. Their temporal distribution is bimodal: a first wave in 2018 coinciding with the consolidation of KKNI-referenced curricula, and a second wave in 2025–2026 concentrating on teacher competency standards and digital enablement. The occupational spread across electrical engineering, geothermal drilling, industrial automation, construction, geomatics, heavy equipment, beauty services, fashion, and software engineering demonstrates the breadth of SKKNI operationalisation. Two absences are decisive for this review: not one national study addresses micro-credentials or digital badges, and not one is situated in mechanical engineering.

Table 4. Characteristics of the national corpus (n = 13)

No	Author (Year)	Context	Focus relevant to SKKNI/KKNI
1	Adriadi, Yasin, & Mairizal (2025)	Construction project management	Competency test standards determining project manager competence
2	Zamtinah & Supriyadi (2018)	Electrical engineering	KKNI descriptor development as the basis of recognition of prior learning
3	Umam, Susilo, Purba, & Adityatama (2020)	Geothermal drilling training	Training curriculum implementing the national competency standard
4	Yuniarti, Pramono, & Anggraenni (2018)	Industrial automation	CIPP evaluation of competency-oriented learning
5	Septama, Ferdiana, & Permanasari (2026)	Software engineering education	Competency-standard-grounded retrieval pipeline for role-based upskilling
6	Widaningsih, Rahayu, Dwiyanti, Widanengsih, & Muktiarni (2025)	TVET teachers	Mapping technical competency needs for Industry 4.0
7	Lubis et al. (2025)	Geomatics, associate degree	Project-based curriculum development referenced to programme outcomes
8	Oroh, Runtuwene, Tumanduk, & Palilingan (2020)	Construction services	Relevance of student productive skills to SKKNI/KKNI-based industry needs

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No	Author (Year)	Context	Focus relevant to SKKNI/KKNI
9	Marwiyah & Apriyani (2018)	Beauty (SPA) education	Industry-linked competence and entrepreneurship in a standardised service field
10	Nilasari & Dasining (2018)	Vocational school, pattern making	Curriculum development based on the INQF and business/industry sector
11	Mandalika, Sukardi, & Minghat (2018)	Vocational school, electricity	Characteristics of expertise competency tests
12	Asfiyanur, Sumardi, Hamdani, & Abdullah (2018)	Heavy equipment industry	Requirement analysis of graduate work competences
13	Widaningsih, Maknun, Dwiyanti, Ramdanisari, & Muktiarni (2025)	TVET teachers	Developing digital education competence standards

b. Alignment mechanisms in the international corpus (RQ1)

Best-fit framework synthesis of the international corpus yielded five recurrent mechanisms through which micro-credentials are aligned with qualifications frameworks and competency standards. The first mechanism is learning-outcome anchoring. The most methodologically explicit study in the corpus, Catenazzi et al. (2025), demonstrates a complete chain in which occupational competence statements are translated into assessable learning outcomes, learning outcomes structure both curriculum and delivery, and digital badges are issued against evidence that the outcomes have been achieved. Ward et al. (2021) generalise this logic into a skills taxonomy designed expressly so that micro-credentials from heterogeneous providers can be accredited against a common reference, while Stankovski (2025) decomposes competences into “micro-competences” referenced to European education frameworks, and Kullaslahti et al. (2019) show standardised digital-competence frameworks operating as the grammar of badge constellations for professional development. Across these studies, the outcome statement, not the course, the provider, or the platform, is the unit of alignment.

The second mechanism is stackability and articulation, by which small credentials accumulate into recognised qualifications. The engineering-technician studies are the clearest exemplars: Kinney et al. (2016) and Kinney et al. (2018) construct stackable credential pathways in robotics and mechatronics through community college-university partnerships expressly designed so that industry-recognised certificates ladder into associate and bachelor qualifications; Khan et al. (2023) embed stackable credentials inside a bridged cybersecurity curriculum; and Wosczyna-Birch (2018) documents machining programmes in which industry credentials are woven into college pathways. The policy studies temper the enthusiasm: de la Torre and Wells (2014) show articulation policy in persistent tension with short-cycle workforce credentials, and Giani and Fox (2017) demonstrate empirically that stackable credentials can either promote upward mobility or reinforce stratification depending on whether pathways genuinely connect onward. Stacking, in other words, is an architectural achievement, not an automatic property of small credentials.

The third mechanism is industry co-design. Alignment in the corpus is repeatedly secured not only through documents but through relationships: manufacturing programmes built with regional industry partners (Wosczyna-Birch, 2018; Kinney et al., 2018), continuing engineering education negotiated with societal and industry needs (Smith & Kálmán, 2023; Kimmel et al., 2022), and assessment personas derived from professional roles (Tubino & Zaidi, 2026). Recent work extends co-design to computational supports, with agentic artificial intelligence assisting the drafting of framework-referenced micro-credential designs (Kemcha et al., 2025). Learner-side evidence completes this mechanism: engineering students value badges chiefly when they perceive them as signals legible to employers (Gregg et al., 2022), which is precisely what standard-referencing provides.

The fourth mechanism is verifiable recognition infrastructure. Saad et al. (2024) identify verification, governance, and stakeholder trust as the principal initial hurdles of institutional micro-credential adoption and examine blockchain-secured badges as a response; Stankovski (2025) similarly couples micro-competence recognition to tamper-evident credential records. The mechanism matters because alignment claims are only as credible as their audit trail: a badge asserting coverage of a standardised competence unit must carry inspectable metadata (the referenced standard, the evidence, the assessor) if third parties are to honour it.

The fifth mechanism is educator capability credentialing: micro-credentials aimed at the teachers and trainers who must design and assess standard-aligned learning. This is the most active recent strand in the corpus, spanning co-designed artificial-intelligence micro-credentials for educators (Hutchins et al., 2025), cybersecurity micro-credentials for teacher professional development (Mugayitoglu et al., 2021), competence-based open badges for teacher education in the EduSTA project (Uusimaki, 2025), standardised pedagogical curricula for engineering educators (Rüütmann & Läänemets, 2025), badge-supported professional development within standardised digital-competence frameworks (Kullaslahti et al., 2019; Park et al., 2025), and micro-credential graduates' own accounts of digital learning ecosystems (Rebola et al., 2025). The corpus also carries a critical register that any adoption must metabolise: Salmon (2023) situates the micro-credential push within employability-driven policy agendas, and Hayes and Rangus (2026) ask what is lost when short credentials substitute for formative depth. These are cautions that alignment design must answer rather than ignore.

c. SKKNI/KKNI operationalisation in the national corpus (RQ2)

The national corpus exhibits four implementation patterns. The first is qualification-framework descriptor development and recognition of prior learning. Zamtinah and Supriyadi (2018) develop KKNI level descriptors for electrical engineering explicitly as the basis of RPL, demonstrating that Indonesian scholarship has already built the levelling-and-recognition logic that micro-credentials require, without yet having a credential format small enough to flow through it.

The second pattern is competency-standard-referenced curriculum development. Umam et al. (2020) design a geothermal drilling training curriculum as a direct implementation of the national competency standard; Nilasari and Dasining (2018) develop vocational school pattern-making curricula from the INQF and business/industry requirements; Lubis et al. (2025) structure a geomatics associate-degree curriculum around programme educational objectives and outcomes within project-based learning; and Marwiyah and Apriyani (2018) link beauty-service education to a standardised industry field. In each case the SKKNI unit of competence functions as the design primitive from which curricula are assembled: the same primitive, at the same granularity, that international studies use to define badge-sized outcomes.

The third pattern is competency assessment, certification, and graduate-industry relevance. Mandalika et al. (2018) characterise expertise competency tests in vocational electricity programmes; Oroh et al. (2020) assess the relevance of students' productive skills against SKKNI- and KKNI-based construction-industry needs; Asfiyanur, Sumardi, Hamdani, and Abdullah (2018) analyse work-competence requirements in the heavy

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equipment industry; Adriadi, Yasin, and Mairizal (2025) examine competing project-manager competency test standards; and Yuniarti et al. (2018) evaluate competency-oriented learning through the CIPP model. This pattern supplies the assessment culture of test characteristics, industry requirement analysis, and programme evaluation onto which credential-level assessment evidence could be grafted.

The fourth pattern is teacher competency standards and digital enablement. Widaningsih, Rahayu, et al. (2025) map the technical competency needs of TVET teachers for Industry 4.0, and Widaningsih, Maknun, et al. (2025) develop digital education competence standards for technical and vocational teachers, while Septama et al. (2026) embed formal competency standards (occupational roles, competency units, and performance indicators) directly into a retrieval-augmented learning pipeline, showing that Indonesian standards are machine-operable design constraints. Taken together, the four patterns show a national research programme that has standardised, levelled, tested, and digitised competence, yet has never issued it in portable, badge-sized form: across all 13 studies there is no occurrence of micro-credentials, digital badges, or stackable credentials, and no mechanical engineering study. This is the gap the present review addresses.

d. Cross-mapping the two corpora

Table 5 cross-maps the five international mechanisms onto anchor points in the Indonesian standards architecture evidenced by the national corpus, and states the design implication of each mapping for mechanical engineering micro-credentials. The mapping is notably tight: every international mechanism finds a pre-existing national anchor, which indicates that the barrier to SKKNI/KKNI-aligned micro-credentials is not architectural but programmatic: the connective design work has simply not yet been done.

Table 5. Cross-mapping of international alignment mechanisms onto the SKKNI/KKNI architecture

International mechanism	SKKNI/KKNI anchor point (national evidence)	Design implication for mechanical engineering micro-credentials
M1. Learning-outcome anchoring (Catenazzi et al., 2025; Ward et al., 2021; Stankovski, 2025)	SKKNI units of competence with elements and performance criteria; standard-referenced curricula (Umam et al., 2020; Nilasari & Dasining, 2018)	Write badge learning outcomes directly from the elements and performance criteria of machining, CNC, welding, and maintenance SKKNI units
M2. Stackability and articulation (Kinney et al.,	KKNI level descriptors and recognition of prior learning (Zamtinah & Supriyadi, 2018)	Design badge clusters that stack toward LSP certification schemes and

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International mechanism	SKKNI/KKNI anchor point (national evidence)	Design implication for mechanical engineering micro-credentials
2016, 2018; Khan et al., 2023; Giani & Fox, 2017)		KKNI-levelled qualifications through the RPL mechanism
M3. Industry co-design (Wosczyna-Birch, 2018; Smith & Kálmán, 2023; Tubino & Zaidi, 2026)	Industry requirement analyses and relevance studies (Asfiyanur et al., 2018; Oroh et al., 2020; Adriadi et al., 2025)	Co-design credential content and assessment with manufacturing industry partners and teaching-factory units
M4. Verifiable recognition infrastructure (Saad et al., 2024; Stankovski, 2025)	BNSP/LSP certification ecosystem and established competency-test practice (Mandalika et al., 2018)	Issue verifiable digital badges carrying standard metadata and assessment evidence inspectable by certification bodies and employers
M5. Educator capability credentialing (Hutchins et al., 2025; Uusimaki, 2025; Mugayitoglu et al., 2021)	TVET teacher competency mapping and digital competence standards (Widaningsih, Rahayu, et al., 2025; Widaningsih, Maknun, et al., 2025)	Credential the productive-course teachers and laboratory instructors who must design, deliver, and assess standard-aligned badges

2. Discussion

The findings answer the third research question by synthesis. Because every international alignment mechanism maps onto an anchor point already built and researched within the Indonesian standards architecture (Table 5), an alignment pathway for mechanical engineering micro-credentials can be constructed as a four-stage design sequence, each stage warranted jointly by the international and national evidence.

The first stage is decomposition. The relevant SKKNI for the target occupation (machining, CNC operation, welding, or mechanical maintenance) is selected and its units of competence are decomposed into elements and performance criteria at badge-sized granularity. This stage transposes the learning-outcome anchoring mechanism (Catenazzi et al., 2025; Ward et al., 2021) onto the design primitive that national curriculum studies already use (Umam et al., 2020; Nilasari & Dasining, 2018). The decisive design judgement is granularity: a credential covering an entire SKKNI unit may be too coarse to be earned within a single laboratory block, while one covering a single performance criterion may be too fine to signal anything an employer values. The micro-competence decomposition logic of Stankovski (2025) suggests that the element level, which typically clusters three to six performance criteria, is the natural badge unit for workshop-based mechanical competences.

The second stage is outcome formulation and assessment design. Each element-level cluster is rewritten as measurable learning outcomes with authentic evidence requirements:

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machined artefacts against tolerance specifications, process documentation, machine set-up records, or supervised task observations. The national assessment culture supplies validated practice for this stage, from the characteristics of expertise competency tests (Mandalika et al., 2018) to industry requirement analyses that specify what evidence employers actually inspect (Asfiyanur et al., 2018; Oroh et al., 2020). The international corpus adds a differentiation principle: assessment should be aligned to the learner persona (initial vocational student, working technician, or career changer) rather than administered uniformly (Tubino & Zaidi, 2026), a principle directly serviceable in Indonesian programmes where the same SKKNI unit is pursued by school students, polytechnic students, and industry employees.

The third stage is verifiable credentialing. Outcomes and evidence are issued as digital badges whose metadata name the referenced SKKNI unit and elements, the assessment instrument, the evidence type, and the assessor's standing. This transposes the recognition-infrastructure mechanism (Saad et al., 2024; Stankovski, 2025) onto the existing BNSP/LSP trust chain rather than in competition with it: the badge does not replace scheme certification but renders visible, portable, and auditable the competence evidence accumulated on the way to it. In this configuration the certification body becomes a consumer of badge evidence, potentially shortening assessment at the certification event, rather than a rival issuer, which addresses the governance and trust hurdles that Saad et al. (2024) identify as the primary obstacle to institutional adoption.

The fourth stage is KKNI levelling and stacking. Badge clusters are mapped onto KKNI level descriptors and connected to recognition of prior learning, so that accumulated credentials ladder into scheme certifications and levelled qualifications. The national warrant for this stage is direct: Zamtinah and Supriyadi (2018) constructed KKNI descriptors precisely as an RPL basis, and the stacking architectures of Kinney et al. (2016), Kinney et al. (2018), and Khan et al. (2023) supply tested structural templates. The equity finding of Giani and Fox (2017) functions here as a design constraint rather than an afterthought: stacked pathways must be built as on-ramps that genuinely connect onward to higher qualifications, because short-cycle credentials that terminate in themselves have been shown to reinforce, not relieve, stratification.

Two enabling conditions cut across the four stages. The first is educator capability. Standard-aligned badges must be designed, taught, and assessed by productive-course teachers and laboratory instructors, and the national corpus shows both that TVET teacher competency needs are being remapped for Industry 4.0 (Widaningsih, Rahayu, et al., 2025) and that digital education competence standards for vocational teachers are under active development (Widaningsih, Maknun, et al., 2025). The international educator-credentialing strand (Hutchins et al., 2025; Mugayitoglu et al., 2021; Uusimaki, 2025) suggests an elegant reflexivity: the teachers' own upskilling can be delivered through the same micro-credential format they will subsequently operate, making educator badges the natural pilot site for the pathway. The second condition is institutional partnership. The community-college studies demonstrate that stackable pathways succeed where educational institutions and regional industry co-own the credential architecture (Wosczyna-Birch, 2018; Kinney et al., 2018); the Indonesian analogue is the teaching factory and the industry-partnered productive unit, which already stage authentic production tasks against which SKKNI-referenced evidence can be generated. Emerging computational supports, such as agentic design assistance (Kemcha et al., 2025) and competency-grounded retrieval pipelines that treat standards as machine-operable constraints (Septama et al., 2026), can lower the design cost of both conditions.

The synthesis must also carry the corpus's critical register. Salmon (2023) shows that micro-credential policy is propelled by employability discourses that can crowd out formative purposes, and Hayes and Rangus (2026) warn against short credentials substituting for depth. The pathway proposed here answers these critiques structurally rather than rhetorically: by anchoring every badge in a public national standard rather than a provider's marketing claim, and by routing accumulation through KKNI levels and RPL rather than an open credential market, alignment converts micro-credentials from market signals into instruments of the public qualification system. Credential inflation is constrained precisely because the reference architecture (SKKNI units, KKNI levels, LSP schemes) is finite, public, and quality-assured.

Three limitations bound these conclusions. First, the review is restricted to Scopus; the national strand therefore underrepresents the substantial SKKNI/KKNI literature published in nationally accredited journals indexed in Sinta and Garuda, and the true national evidence base is certainly larger than 13 studies, though there is no indication that its silence on micro-credentials would differ. Second, the corpus is methodologically heterogeneous and dominated by conference papers, which limited quality-appraisal weighting and confines the synthesis to mechanism identification rather than effect estimation. Third, the alignment pathway is a conceptual synthesis: its four stages are individually evidenced, but the pathway as a whole has not been empirically enacted, and its validation, ideally through educational design research in a mechanical engineering programme, remains the necessary next step.

CONCLUSION

Conclusion

This systematic review set out to bridge two literatures that had developed in parallel. From 47 Scopus records, 37 studies were synthesised: an international corpus of 24 studies on aligning micro-credentials with qualifications frameworks and competency standards, and a national corpus of 13 studies operationalising SKKNI and KKNI in engineering and vocational education. The international corpus yields five alignment mechanisms: learning-outcome anchoring, stackability and articulation, industry co-design, verifiable recognition infrastructure, and educator capability credentialing. The national corpus shows a mature standards architecture (descriptor development and recognition of prior learning, standard-referenced curricula, competency assessment and certification, and teacher competency standards) that contains no study connecting micro-credentials to SKKNI or KKNI, and none situated in mechanical engineering. Cross-mapping demonstrates that every international mechanism has a pre-existing national anchor, and on that basis the review contributes a four-stage alignment pathway, comprising decomposition of SKKNI units to badge-sized elements, outcome formulation with authentic assessment evidence, verifiable credentialing interoperable with the BNSP/LSP trust chain, and KKNI levelling with stacking through recognition of prior learning, as a design basis for micro-credentials in Indonesian vocational mechanical engineering education.

Suggestions

Three recommendations follow. For programme managers in vocational mechanical engineering, the element level of machining, CNC, welding, and maintenance SKKNI units

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offers the natural granularity at which to pilot badge design within teaching-factory and laboratory courses, with educator micro-credentials as the most strategic first pilot. For policy actors in vocational education, manpower, and professional certification, the priority is an interoperability rule that lets certification bodies consume badge evidence within scheme assessment and RPL, so that micro-credentials strengthen rather than bypass the national qualification system. For researchers, two extensions are most urgent: replication of the national strand across Sinta- and Garuda-indexed literature to test the robustness of the gap, and educational design research that enacts and evaluates the four-stage pathway in a mechanical engineering programme, converting the conceptual contribution of this review into validated design knowledge.

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