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# Micro-Credentials for STEM Competency Recognition in Vocational Education: A Systematic Review of Recognition Architectures and Evidence Gaps

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**Abstract**

Micro-credentials are widely promoted as a mechanism for making granular competencies visible, yet it remains unclear whether the accumulated evidence actually supports competency recognition in the settings where technical skills are formed. This study is a systematic mapping review, conducted on a single database (Scopus) and reported under the PRISMA 2020 statement, that asks how the literature on micro-credentials and digital badges addresses competency recognition, and how far that literature reaches STEM domains and vocational education. Because the aim is to characterise the distribution of research rather than to pool effect sizes, the review is diagnostic rather than evaluative. Five concentric Scopus query sets were executed on 15 August 2026, yielding 221 records. After the removal of 31 duplicates and the screening of 190 records against four inclusion criteria, 138 studies published between 2014 and 2026 were retained and coded on educational sector, disciplinary domain, thematic focus, research design, and country of affiliation. The 138 studies were coded on educational sector, disciplinary domain, thematic focus, research design, and country of affiliation through a rule based lexical scheme followed by manual adjudication of vocational and borderline cases. The corpus grows sharply from 2023 onward, with 93 studies (67.4 percent) published in the final four years. STEM, engineering, and computing constitute the largest disciplinary domain with 45 studies (32.6 percent), yet only 13 studies (9.4 percent) are situated in technical and vocational education and training, and only 7 studies (5.1 percent) sit at the intersection of the two. Six thematic clusters were identified inductively and then arranged, through a best fit framework logic, onto a four layer recognition architecture that runs from competency standards through learning evidence and credential metadata to labour market value. This architecture, together with the evidence density quantified at each layer, is the principal contribution of the review. Evidence density is highly uneven across the layers, and the vocational share is thinnest precisely where credential infrastructure is discussed. Because the corpus is drawn from one database, these patterns describe the Scopus indexed literature and are read as an absence of evidence in that corpus rather than as proof that the underlying practice is absent. The review concludes that micro-credential scholarship has matured as a higher education phenomenon while leaving the vocational recognition problem largely unexamined, and it sets out a research agenda that connects credential design to national competency standards, workplace assessment, and employer trust.

Keywords: Micro-Credentials, Competency Recognition, Vocational Education, STEM Education, Systematic Mapping Review

## INTRODUCTION

Contemporary labour markets change faster than the qualification systems designed to describe them. Technological upgrading in manufacturing, construction, energy, and information technology reshapes the competency profile of technical occupations within a few years, while a diploma or a degree certifies a bundle of learning that was defined much earlier and is rarely revisited. The resulting mismatch is not only a matter of curriculum content. It is also a recognition problem, because employers, training providers, and learners lack a shared instrument for describing what a person can actually do at a level of granularity finer than a whole qualification. Micro-credentials, together with the digital badges and verifiable credentials that carry them, have been proposed as exactly that instrument.

The policy momentum behind these instruments is considerable. National and supranational bodies have issued definitions, quality principles, and portability guidance, and higher education institutions have responded with portfolios of short, stackable offerings (Caetano et al., 2023; John & Hürten, 2025; Toledo-Navarrete et al., 2026). The scholarly response has followed, producing a body of work that now includes several syntheses of the higher education experience (Ahsan et al., 2023; Yıldırım et al., 2025; Wenjing et al., 2026). Within this literature a recurring claim is that micro-credentials make competence visible in ways that conventional transcripts cannot, and that this visibility improves mobility between education and work (Moodie & Wheelahan, 2021; Varadarajan et al., 2023).

That claim is most consequential in the sector where competence is most explicitly the object of instruction. Technical and vocational education and training exists to produce demonstrable occupational capability, is already organised around competency units, and already operates a machinery of workplace assessment and industry certification. If granular digital recognition has a natural home, vocational education is it. In Indonesia, for instance, the national competency standard system and the national qualification framework provide a ready made unit of granularity, and vocational schools and polytechnics routinely certify competence through independent assessment bodies. The question is whether the international research literature has actually engaged with this setting, or whether it has developed as a higher education conversation that vocational systems are expected to adopt without a corresponding evidence base.

Two observations motivate the present review. First, existing syntheses of micro-credential research are predominantly framed around higher education institutions and their strategic responses, and where they consider skills they tend to treat the skill as a generic attribute rather than a standardised occupational competency (Ahsan et al., 2023; Varadarajan et al., 2023; Durak et al., 2026). Second, the technical strand of the literature, which develops badge infrastructure and verifiable credential architectures, has expanded rapidly and largely independently of the pedagogical strand (Jirgensons & Kapenieks, 2018; Razzaq et al., 2026). Neither observation has been tested against a corpus assembled specifically to ask where STEM competency recognition and vocational education sit within the field.

These observations also mark where the present review departs from existing syntheses. Recent systematic reviews of micro-credentials concentrate on higher education implementation and stakeholder value (Ahsan et al., 2023; Varadarajan et al., 2023; Yıldırım et al., 2025); bibliometric and thematic reviews chart publication trends and keyword structures in open and distance learning (Durak et al., 2026); and scoping reviews describe national stackable credential ecosystems (Toledo-Navarrete et al., 2026). None of these assembles a corpus for the explicit purpose of locating STEM competency recognition and vocational education within the field, cross-tabulates educational sector against disciplinary domain, or converts the resulting thematic structure into a layered account of where evidence is dense and where it is missing. The contribution of the present review lies in that combination: a sector by domain map of the field, and a recognition architecture that functions as an evidence gap instrument rather than as a descriptive summary.

This review therefore maps the literature on micro-credentials and digital badges for competency recognition, and locates the STEM and vocational portion of that literature within it. The purpose is diagnostic rather than evaluative. Rather than asking whether micro-credentials work, which the current evidence base cannot answer with confidence, the review asks what the field has actually studied, in which settings, using which designs, and where the structural gaps lie for vocational systems that are being asked to adopt these instruments. Four research questions guide the analysis:

RQ1. How has scholarship on micro-credentials for competency recognition developed between 2014 and 2026 in terms of publication volume, document type, publication venue, and geographical distribution?

RQ2. Which educational sectors and disciplinary domains does this scholarship cover, and what proportion of it addresses STEM domains and vocational education?

RQ3. What thematic concerns organise the literature, and how do those concerns map onto an architecture of competency recognition?

RQ4. Which research designs underpin the evidence base, and where do the evidence gaps for STEM competency recognition in vocational education lie?

Each question is answered by a distinct analytical output. RQ1 and RQ2 are addressed by the descriptive synthesis and by the cross-tabulation of educational sector against disciplinary domain. RQ3 is addressed by the thematic synthesis and by its arrangement into the recognition architecture. RQ4 is addressed by the evidence gap matrix, which intersects that architecture with the sector and domain codes. The four questions therefore move from describing the field, through locating STEM and vocational work within it, to diagnosing where the evidence for vocational systems is missing.

The contribution of this review is threefold. It supplies a transparent and reproducible account of the field assembled under PRISMA 2020 reporting standards, with search strings, eligibility rules, and exclusion counts stated in full. It derives a four layer recognition architecture from the thematic structure of the corpus and quantifies the evidence density at each layer, which converts a descriptive map into a diagnostic instrument. Finally, it specifies a research agenda for vocational systems that connects credential design to national competency standards, workplace assessment, and employer trust, three concerns that the reviewed literature raises but rarely addresses together.

## METHOD

### Review design

The study is a systematic mapping review: its purpose is to chart the extent, range, and distribution of research on micro-credentials for competency recognition, not to appraise or pool the outcomes of individual studies (Grant & Booth, 2009). The review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement for identification, screening, eligibility assessment, and reporting (Page et al., 2021). The procedural sequence of assembling, arranging, and assessing the corpus is organised according to the SPAR-4-SLR protocol (Paul et al., 2021), which suits domain reviews in which the goal is to characterise a field rather than to pool effect sizes. Synthesis proceeds thematically, using the inductive and deductive procedure described by Thomas and Harden (2008) and refined into a best fit framework logic by Carroll et al. (2013), so that codes generated from the corpus are subsequently arranged against an a priori recognition structure. Because the included studies are heterogeneous in design and outcome, no statistical meta-analysis was attempted. For the same reason, and because screening and coding operate on bibliographic metadata rather than on full texts, no formal quality appraisal or risk of bias assessment of individual studies was undertaken. This is a deliberate boundary of a mapping review, which reports where studies are and what they address rather than how internally valid each one is; the consequence, carried into the reading of every result below, is that the review supports claims about the distribution and framing of the evidence but not about the strength of the findings within the studies mapped.

### Data source and search strategy

Scopus was selected as the single source database. The choice reflects three considerations: its coverage of both educational research and the engineering and computing venues in which credential infrastructure is published, its consistent metadata schema across document types, and its export format, which supports reproducible offline processing. The trade off is that publications indexed only in Web of Science, ERIC, or regional databases are absent, and this is acknowledged as a limitation. Scopus was nonetheless preferred over the principal alternative because its journal coverage is broader than that of Web of Science across the social sciences and engineering, the two literatures this review must span (Mongeon & Paul-Hus, 2016). The single source decision is also consistent with the diagnostic purpose stated above: the objective is to characterise how the field is distributed across sectors, domains, and themes, not to estimate a pooled effect for which the omission of eligible studies would bias a summary statistic. A single well structured database with a consistent metadata schema further delivers a reproducibility and internal comparability that a multi database merge, with its heterogeneous fields and uneven de-duplication, does not. The consequence, made explicit throughout the analysis and revisited in the limitations, is that every count reported here describes the Scopus indexed literature, so a thin or empty cell is read as an absence of evidence in that corpus rather than as evidence that the corresponding practice does not exist elsewhere.

Five query sets were executed on 15 August 2026. The sets were designed as concentric rings rather than as a single string, beginning with a broad credential and badge ring and narrowing progressively toward the vocational and STEM intersection. This design was adopted deliberately: a single narrow string would have returned too few records to characterise the field, while a single broad string would have buried the vocational studies among infrastructure papers. Table 1 reports the concept blocks, the Boolean strings, and the number of records retrieved by each set.

The terms within each block were chosen to reflect the vocabulary the field actually uses rather than a single preferred label. The credential block therefore combines the hyphenated and closed spellings of micro-credential, the badge family (digital badge, open badge), and the wider family of alternative, digital, and non-degree credentials, because these labels are used interchangeably across the pedagogical and policy literatures. Truncation wildcards capture morphological variants, so that micro-credential* also retrieves micro-credentials and micro-credentialing, and competenc* retrieves competence, competency, and competencies. The blockchain and certificate pairing was placed in the broad ring deliberately, to surface the credential infrastructure strand, in the knowledge that it would also return cryptographic records with no educational content; those records were subsequently removed at screening under criterion EC3, and their volume is itself reported as a finding.

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Table 1. Search strategy, query sets, and records retrieved

| Set | Concept blocks | Boolean string executed in Scopus | Records |
|---|---|---|---|
| Q1 | Credential or badge terminology (broad ring) | TITLE-ABS-KEY ( ( "micro-credential*" OR "microcredential*" OR "digital badge*" OR "open badge*" OR "digital credential*" OR "alternative credential*" ) OR ( "blockchain" AND ( "credential*" OR "certificate*" ) ) ) | 174 |
| Q2 | Credential or badge AND STEM or competency | TITLE-ABS-KEY ( ( "micro-credential*" OR "microcredential*" OR "digital badge*" OR "open badge*" ) AND ( "STEM" OR "engineering education" OR "computer science education" OR "competenc*" OR "skill recognition" ) ) | 34 |
| Q3 | Credential AND vocational sector | TITLE-ABS-KEY ( ( "micro-credential*" OR "microcredential*" ) AND ( "TVET" OR "vocational education" OR "vocational training" OR "community college" OR "polytechnic" ) ) | 8 |
| Q4 | Credential AND micro-competence or VET teacher | TITLE-ABS-KEY ( ( "microcredential*" OR "open badge*" ) AND ( "microcompetenc*" OR "vocational teacher*" OR "VET" ) ) | 3 |
| Q5 | Credential AND TVET AND assessment or pedagogy | TITLE-ABS-KEY ( "micro-credential*" AND "TVET" AND ( "assessment" OR "pedagog*" ) ) | 2 |
| | Total records exported | | 221 |

**Eligibility criteria**

Four inclusion criteria and five exclusion criteria were specified before screening. The criteria are designed to separate three things that the raw search results conflate: studies in which a credential is an educational recognition artefact, studies in which credential terminology refers to a cryptographic identity object with no learning content, and studies in which a badge functions purely as a game mechanic. Only the first category answers the research questions. Table 2 states the criteria and the decision rule applied to each.

Table 2. Inclusion and exclusion criteria with decision rules

| Code | Criterion | Decision rule applied to the record |
|---|---|---|
| IC1 | Published in English | The Scopus language field records English as the language of the original document. |
| IC2 | Research or scholarly document | Document type is article, review, conference paper, book, or book chapter. |
| IC3 | Credential is a substantive object of study | Title, abstract, or author keywords contain micro-credential, microcredential, digital badge, open badge, digital credential, alternative credential, non-degree credential, stackable credential, |

| | | |
|---|---|---|
| | | nanodegree, micro-competence, badging, or verifiable credential. |
| IC4 | Situated in education, training, or workforce development | The record refers to learners, students, teaching, curriculum, courses, schools, universities, colleges, professional development, upskilling, reskilling, workforce development, or lifelong learning. |
| EC1 | Not published in English | Excluded regardless of topical fit. |
| EC2 | Non-research document type | Editorials and front matter excluded. |
| EC3 | No credential or badge focus | Credential or certificate terminology appears only in a cryptographic, network security, supply chain, or identity management sense with no educational recognition purpose. |
| EC4 | No education, training, or workforce context | The credential is applied outside any learning or workforce development setting, for example in gig platform reputation or health status verification. |
| EC5 | Badge as gamification only | The badge functions solely as a points or reward mechanic, with no claim that it evidences competence. |

**Screening and selection**

The five exported files were merged into a single working corpus of 221 records. Duplicate detection was performed in two passes, first on the digital object identifier and then on a normalised title string with punctuation, spacing, and case removed. This procedure removed 31 duplicates and left 190 unique records. It is worth noting that query set Q5 contributed no unique record at all, both of its results having already been retrieved by broader sets, which is itself a signal that the vocational corner of this literature is small enough to be exhausted quickly.

Each of the 190 unique records was then screened against the criteria in Table 2 using the title, abstract, and keyword fields. Screening produced 52 exclusions, distributed across the five exclusion codes as reported in Table 3, and retained 138 studies. The dominant exclusion reason, accounting for 40 of the 52 removals, was the presence of credential terminology in a purely cryptographic sense. Records in this group addressed phishing certificate detection, electronic voting authentication, supply chain traceability, and similar concerns, and were retrieved because the broad Q1 ring deliberately included the blockchain and certificate combination. Their removal is the clearest illustration of why an explicit recognition criterion was necessary. Figure 1 presents the full PRISMA 2020 flow.

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Table 3. Records excluded at the screening stage with reasons

| Code | Reason for exclusion | Records | Share of exclusions |
|---|---|---|---|
| EC3 | Credential terminology used in a cryptographic, security, or identity sense only | 40 | 76.9% |
| EC4 | No education, training, or workforce development context | 5 | 9.6% |
| EC5 | Badge treated only as a gamification element | 4 | 7.7% |
| EC1 | Not published in English | 2 | 3.8% |
| EC2 | Non-research document type | 1 | 1.9% |
| | Total excluded | 52 | 100.0% |

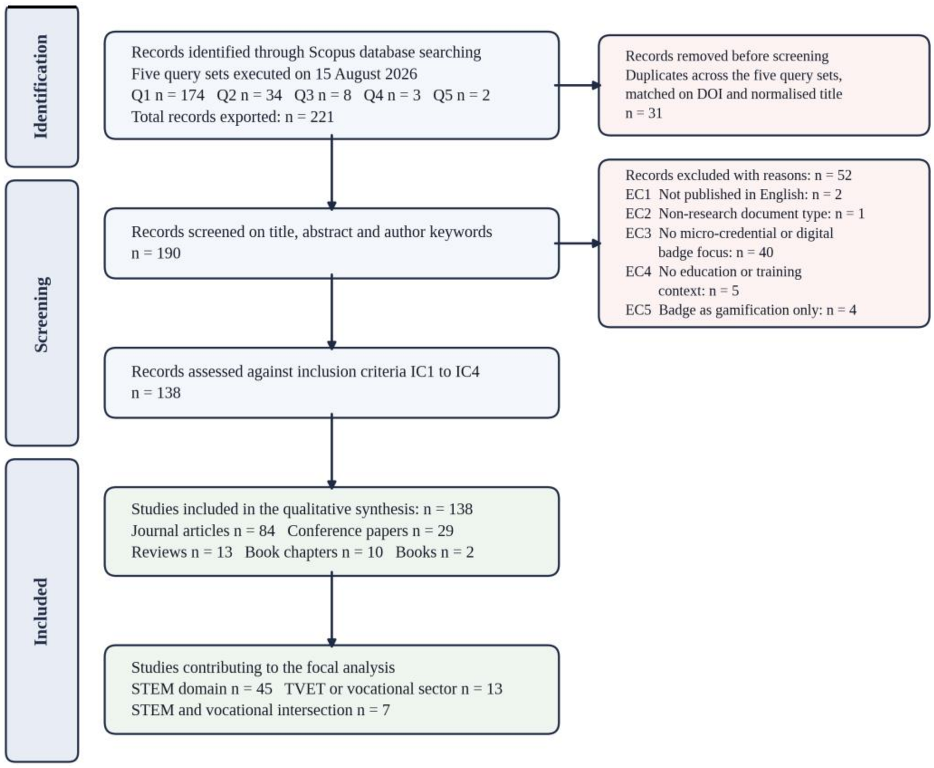


Figure 1. PRISMA 2020 flow diagram of the review process

**Data extraction and coding**

Every included record was coded on five dimensions. Bibliographic fields, namely year, document type, source title, citation count, open access status, and author affiliation country, were extracted directly from the Scopus export. Four analytical dimensions, namely educational sector, disciplinary domain, thematic focus, and research design, were assigned by applying a rule based lexical scheme to the combined title, abstract, and keyword text of each record. Table 4 sets out the scheme.

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The rule based pass was followed by manual adjudication. Every record assigned to the vocational sector was re-read to confirm that the vocational reference was substantive rather than incidental, and every record whose classification depended on a single ambiguous term was re-read before the assignment was accepted. Records excluded at the boundary of criteria IC3, IC4, and EC5 were likewise adjudicated individually. Where a record legitimately touched more than one category, precedence was assigned to the most specific category, so that a study of an information technology programme in a community college was coded to the vocational sector rather than to higher education. Two features of this procedure support the consistency of the coding despite the absence of a second independent coder. First, the initial pass is rule based rather than interpretive: because each analytical dimension is assigned by an explicit lexical rule applied to a fixed metadata field, the first pass classification is deterministic and can be reproduced exactly by any researcher applying the same dictionary, which is retained as supplementary material. Second, interpretive judgement was confined to a defined set of cases, namely the vocational and borderline assignments described above, each of which was re-read against the abstract and adjudicated under the precedence rule, with the decision recorded. The residual limitation is that no independent double coding was performed and therefore no inter-rater reliability statistic is reported; this bears on the interpretive minority of assignments rather than on the deterministic majority, and it is restated among the limitations.

Table 4. Coding scheme applied to the 138 included studies

| Dimension | Categories | Assignment rule |
|---|---|---|
| Educational sector | TVET and vocational; higher education; school (K-12); teacher professional development; workforce and corporate; cross-sector or unspecified | Assigned to the most specific setting named in the record. Vocational markers, namely TVET, vocational, polytechnic, apprenticeship, community college, further education, and work based learning, take precedence over general higher education markers. |
| Disciplinary domain | STEM, engineering, and computing; health sciences; business and management; education and teaching; humanities, languages, and social sciences; discipline-neutral or multiple | Assigned on the substantive subject matter of the credential described. Records with no subject anchor, for example institutional policy studies, were coded as discipline-neutral. |
| Thematic focus | Recognition architecture and frameworks; assessment and quality assurance; credentialing technology and infrastructure; curriculum and instructional design; learner | Assigned to the cluster with the strongest lexical signal across the record, then verified by reading the abstract. Each study received exactly one primary theme. |

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| | | |
|---|---|---|
| | motivation and engagement; employability and labour market value | |
| Research design | Empirical study; conceptual or position paper; review or bibliometric study; design or development study | Review status was assigned when the document type was a review or when the abstract described a systematic, scoping, or bibliometric procedure. Design or development was assigned when the study reported the construction and evaluation of an artefact. |
| Geography | Country of author affiliation | Every distinct country appearing in the affiliation field was counted once per record, so that a co-authored study contributes to more than one country total. |

**Synthesis procedure**

Synthesis proceeded in three movements. Descriptive synthesis addressed RQ1 and RQ2 through frequency and cross-tabulation of the coded dimensions. Thematic synthesis addressed RQ3 in two stages. In the first, inductive stage, the primary theme codes were generated from the corpus without a predetermined category list and consolidated through constant comparison into the six clusters reported in Table 8. In the second, deductive stage, these six clusters were arranged, following the best fit framework logic of Carroll et al. (2013), onto an a priori functional structure that treats competency recognition as a sequence of problems any recognition system must solve: what competence is claimed, how the claim is evidenced, how the claim is expressed and transported, and whether the claim is honoured. The synthesis is therefore inductive in its categories and theoretically informed in their ordering, and the full mapping of clusters onto layers is stated in Table 9 when the architecture is presented. Gap analysis addressed RQ4 by intersecting the layer structure with the sector and domain codes, so that the density of evidence at each layer could be read separately for STEM studies and for vocational studies. This last step converts the descriptive map into a diagnostic instrument, because it shows not only what is studied but where the vocational sector is missing from what is studied.

## RESULTS & DISCUSSION

**Development of the field between 2014 and 2026**

The 138 included studies span thirteen publication years, from 2014 to 2026, but the distribution across those years is strongly skewed toward the recent period. Figure 2 shows a field that accumulates slowly through the second half of the 2010s and then expands sharply.

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Ninety three studies, amounting to 67.4 percent of the corpus, appeared in the four years from 2023 onward, and 118 studies, or 85.5 percent, appeared from 2020 onward. The single largest annual output falls in 2026 with 34 studies, a figure that was reached by mid August of that year and therefore understates the eventual total.

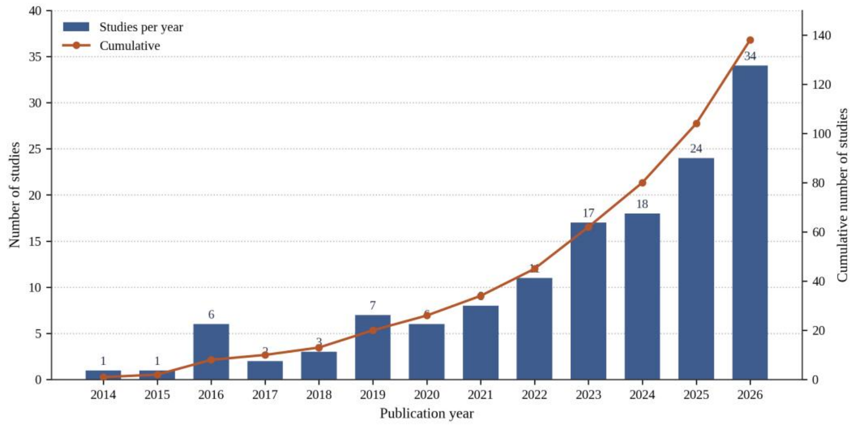


Figure 2. Annual and cumulative distribution of the 138 included studies

Two forces plausibly drive this pattern. The pandemic period normalised short, modular, online provision and created an institutional appetite for recognising learning completed outside conventional programme structures (Farias-Gaytan et al., 2023; Caetano et al., 2023). Subsequently, the maturation of policy instruments at national and supranational level supplied definitions and quality expectations that gave researchers a stable object to study (John & Hürten, 2025; Toledo-Navarrete et al., 2026; Kicherova et al., 2026). The rapid growth also means that the field is young in a specific sense: much of what has been published has not yet been cited or contested.

The composition of the corpus by document type and research design supports that reading. Journal articles account for 84 studies (60.9 percent), conference papers for 29 (21.0 percent), reviews for 13 (9.4 percent), book chapters for 10 (7.2 percent), and books for 2 (1.4 percent). Empirical studies constitute 48 records (34.8 percent), conceptual and position papers 45 (32.6 percent), reviews and bibliometric studies 25 (18.1 percent), and design or development studies 20 (14.5 percent). Taken together, conceptual, review, and design work outnumber empirical work by roughly two to one. A further indication of immaturity is the citation profile: total citations across the corpus amount to 1,482, with a mean of 10.7 and a median of only 2, and 50 studies (36.2 percent) have not been cited at all. Table 5 summarises the profile.

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Table 5. Profile of the 138 included studies

| Dimension | Category | n | % |
|---|---|---|---|
| Document type | Journal article | 84 | 60.9 |
| | Conference paper | 29 | 21.0 |
| | Review | 13 | 9.4 |
| | Book chapter | 10 | 7.2 |
| | Book | 2 | 1.4 |
| Research design | Empirical study | 48 | 34.8 |
| | Conceptual or position paper | 45 | 32.6 |
| | Review or bibliometric study | 25 | 18.1 |
| | Design or development study | 20 | 14.5 |
| Publication period | 2014 to 2019 | 20 | 14.5 |
| | 2020 to 2022 | 25 | 18.1 |
| | 2023 to 2026 | 93 | 67.4 |
| Access status | Open access | 132 | 95.7 |
| | Subscription only | 6 | 4.3 |
| Citation impact | Uncited | 50 | 36.2 |
| | 1 to 9 citations | 57 | 41.3 |
| | 10 or more citations | 31 | 22.5 |

The very high open access share, 132 of 138 studies, deserves comment. It partly reflects the publication cultures of educational technology and engineering education, where open venues predominate, and partly reflects the retrieval behaviour of the query sets. Readers should therefore treat the corpus as well covered but potentially skewed toward openly available scholarship.

Table 6 lists the ten most cited studies. The list is instructive because of what sits at the top. The single most cited work in the corpus is a blockchain oriented account of credential assessment and management (Jirgensons & Kapenieks, 2018), followed by two higher education focused systematic reviews (Varadarajan et al., 2023; Ahsan et al., 2023) and a broad review of fourth industrial revolution technologies in higher education (Chaka, 2023). Only one study in the top ten reports a discipline specific assessment intervention, namely the use of peer review and digital badges to develop laboratory skills in chemistry (Seery et al., 2017). The attention structure of the field, in other words, currently rewards infrastructure and institutional policy far more than it rewards evidence about competence.

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Table 6. Ten most cited studies in the corpus

| No | Study | Year | Source | Primary Theme | Citations |
|---|---|---|---|---|---|
| 1 | Jirgensons & Kapenieks | 2018 | Journal of Teacher Education for Sustainability | Credentialing technology | 206 |
| 2 | Varadarajan et al. | 2023 | International Journal of Educational Technology in Higher Education | Employability and value | 169 |
| 3 | Ahsan et al. | 2023 | Education and Information Technologies | Recognition architecture | 115 |
| 4 | Chaka | 2023 | Research and Practice in Technology Enhanced Learning | Credentialing technology | 113 |
| 5 | Seery et al. | 2017 | Chemistry Education Research and Practice | Assessment and quality | 81 |
| 6 | Ahmat et al. | 2021 | Asian Journal of University Education | Employability and value | 69 |
| 7 | Ward et al. | 2021 | IEEE Global Engineering Education Conference | Recognition architecture | 41 |
| 8 | Bell & Davis | 2016 | Proceedings of Interaction Design and Children | Learner motivation | 37 |
| 9 | Kiiskilä et al. | 2023 | SN Computer Science | Credentialing technology | 36 |
| 10 | Roy & Clark | 2019 | British Journal of Educational Technology | Learner motivation | 30 |

**Geographical distribution**

Author affiliations in the corpus resolve to 52 distinct countries across 184 country mentions. Figure 3 presents the distribution. Europe accounts for 87 mentions (47.3 percent), the Asia-Pacific region for 39 (21.2 percent), North America for 35 (19.0 percent), Latin America and the Middle East for 9 each (4.9 percent), and Africa for 5 (2.7 percent). At country level the United States leads with 29 studies, followed by the United Kingdom with 13, Australia with 11, Spain with 10, and Italy with 8. Malaysia and Ireland follow with 7 each.

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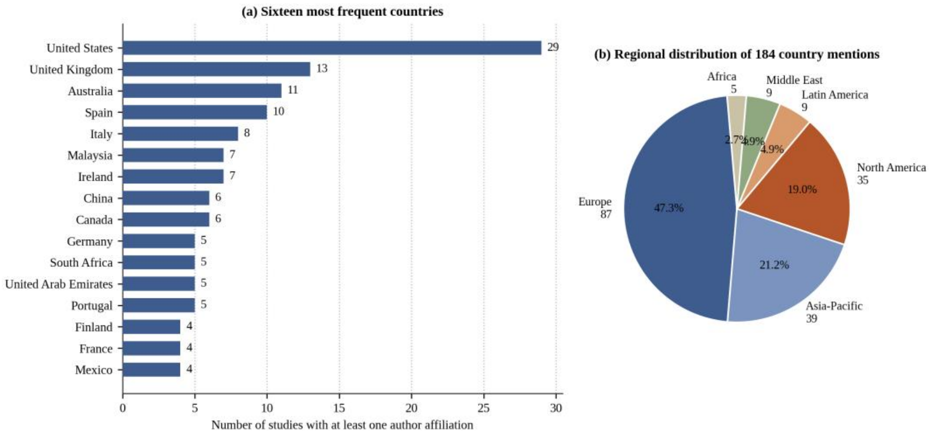


Figure 3. Geographical distribution of the included studies

The European concentration is unsurprising given the density of regional credential policy work, and it is visible in the corpus through studies that operationalise European competence frameworks and digital credential standards (Martín-Ramos et al., 2025; John & Hürten, 2025; Martín-Ramos et al., 2025). The Asia-Pacific presence is more interesting for the purposes of this review because it is disproportionately vocational. Malaysia contributes work on micro-credential curriculum development for community colleges (Techanamurthy et al., 2024) and on open badge guideline design (Halili et al., 2024), while Chinese work addresses employment quality for vocational college graduates in an intelligent construction context (Cai, 2026). Indonesia appears in only 2 of the 138 studies, one of which examines whether digital micro-credentials enhance employability and career awareness (Rullyana et al., 2026). Given the scale of the Indonesian vocational system, this is a striking under-representation and one of the clearest openings identified by this review. Only 25 studies (18.1 percent) involve authors from more than one country, which suggests that credential research remains largely a national conversation even where the policy instruments are explicitly transnational.

**Sectoral and disciplinary coverage**

The second research question concerns where this literature is situated. The answer is unambiguous. Higher education accounts for 79 studies (57.2 percent), cross-sector or unspecified settings for 22 (15.9 percent), workforce and corporate settings for 17 (12.3 percent), technical and vocational education and training for 13 (9.4 percent), schooling for 5 (3.6 percent), and teacher professional development for 2 (1.4 percent). By disciplinary domain, STEM, engineering, and computing form the largest single group with 45 studies (32.6 percent), ahead of discipline-neutral work with 34 (24.6 percent), education and teaching with 22 (15.9 percent), health sciences with 19 (13.8 percent), business and management with 13 (9.4 percent), and humanities, languages, and social sciences with 5 (3.6 percent). Table 7 and Figure 4 present the cross-tabulation.

Table 7. Distribution of the 138 studies by educational sector and disciplinary domain

| Sector | STEM | Neutral | Education | Health | Business | Humanities | Total |
|---|---|---|---|---|---|---|---|
| Higher education | 20 | 23 | 13 | 12 | 8 | 3 | 79 |
| Cross-sector or unspecified | 9 | 3 | 3 | 2 | 3 | 2 | 22 |
| Workforce and corporate | 6 | 5 | 3 | 2 | 1 | 0 | 17 |
| TVET and vocational | 7 | 2 | 1 | 2 | 1 | 0 | 13 |
| School (K-12) | 2 | 1 | 1 | 1 | 0 | 0 | 5 |
| Teacher professional development | 1 | 0 | 1 | 0 | 0 | 0 | 2 |
| Total | 45 | 34 | 22 | 19 | 13 | 5 | 138 |

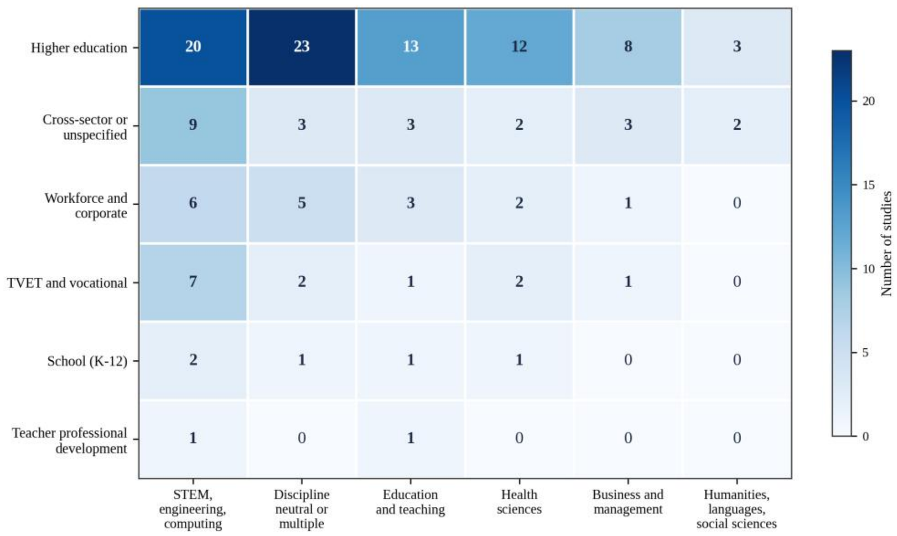


Figure 4. Cross-tabulation of educational sector and disciplinary domain (n = 138)

Three readings follow from this table. First, the disciplinary claim implicit in the planned framing of this review is confirmed: STEM is genuinely the centre of gravity of micro-credential research, and it is the largest domain in four of the six sectors. Technical and computing competencies lend themselves to granular decomposition, which is precisely the property that micro-credentials exploit (Ward et al., 2021; Parrales-Bravo, 2026). Second, the sectoral claim is not confirmed. Vocational education holds 9.4 percent of the corpus, and the cell that matters most for this review, the intersection of STEM domains with vocational settings, contains only 7 studies, which is 5.1 percent of the corpus. Third, the higher education row is sufficiently dominant that generalisations drawn from the field as a whole are, in practice, generalisations about universities.

The seven studies at the STEM and vocational intersection are worth naming individually, because they constitute the entire empirical and conceptual foundation currently available for the question that vocational systems are asking. They cover micro-credential curriculum development for internet of things instruction in Malaysian community colleges (Techanamurthy et al., 2024), accelerated optics workforce development through condensed skill building (Parada et al., 2024), artificial intelligence supported pedagogy and assessment in technical and vocational education (Faisal et al., 2025), employment quality pathways for vocational college graduates in intelligent construction (Cai, 2026), non-degree credentialing for STEM workforce development (Zinnah et al., 2025), the alignment of academic and everyday learning across vocational and apprenticeship routes (Cheng & Liu, 2026), and post-pandemic leadership perspectives that touch vocational provision (Newmann & Rosedale, 2025). Even within this small set, the modal contribution is programme description rather than evaluated outcome.

The design profile of the vocational subset reinforces the point. Of the 13 vocational studies, 7 are conceptual or position papers, 3 are empirical, 2 are design or development studies, and 1 is a review. By contrast, the 45 STEM studies distribute more evenly across 15 conceptual, 14 empirical, 10 design or development, and 6 review contributions. Vocational education is therefore not merely under-represented in volume; it is under-represented specifically in the categories of work that generate evidence.

**Thematic structure of the literature**

Six primary themes emerged from the coding, and their distribution is reported in Table 8. Recognition architecture and frameworks is the largest cluster with 44 studies (31.9 percent), followed by assessment and quality assurance with 30 (21.7 percent), credentialing technology and infrastructure with 20 (14.5 percent), employability and labour market value with 17 (12.3 percent), curriculum and instructional design with 14 (10.1 percent), and learner motivation and engagement with 13 (9.4 percent). Figure 5 disaggregates each cluster by research design.

Table 8. Thematic clusters, their scope, and representative studies

| Cluster | Scope of the cluster | n | % | Representative studies |
|---|---|---|---|---|
| Recognition architecture and frameworks | Qualification frameworks, credit and stackability, policy and governance, standards for what a credential must represent | 44 | 31.9 | Moodie & Wheelahan (2021); Ahsan et al. (2023); Yıldırım et al. (2025); Toledo-Navarrete et al. (2026) |

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| Cluster | Scope of the cluster | n | % | Representative studies |
|---|---|---|---|---|
| Assessment and quality assurance | Evidence requirements, rubrics and criteria, endorsement, programme evaluation, validity of the competence claim | 30 | 21.7 | Seery et al. (2017); Everhart et al. (2016); Tammeleht & Rajando (2024); Tubino & Zaidi (2026) |
| Credentialing technology and infrastructure | Badge metadata standards, blockchain and verifiable credential architectures, interoperability, issuance at scale | 20 | 14.5 | Jirgensons & Kapenieks (2018); Kiiskilä et al. (2023); Tanim et al. (2026); Andrian & Wiputra (2026) |
| Employability and labour market value | Employer perception and trust, hiring signals, career outcomes, articulation with employment | 17 | 12.3 | Varadarajan et al. (2023); Aerne & Bonoli (2026); Zinnah et al. (2025); Alenezi et al. (2024) |
| Curriculum and instructional design | Modularisation, micro-learning design, delivery models, mapping of credentials onto programme structures | 14 | 10.1 | Techanamurthy et al. (2024); Parada et al. (2024); Catenazzi et al. (2025); Parrales-Bravo (2026) |
| Learner motivation and engagement | Learner perception, motivation and persistence, identity and engagement effects of badging | 13 | 9.4 | Roy & Clark (2019); Bell & Davis (2016); Mistretta et al. (2022); van de Laar et al. (2024) |

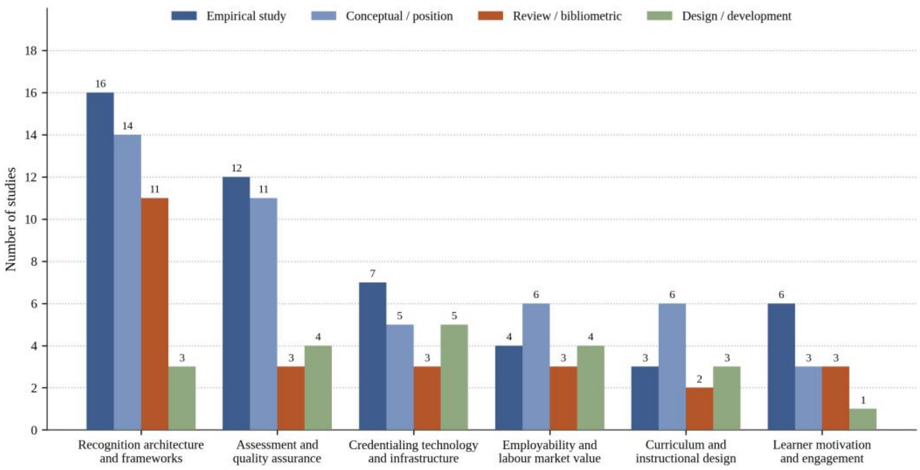


Figure 5. Thematic clusters by research design (n = 138)

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***Recognition architecture and frameworks***

This cluster addresses the prior question of what a credential is permitted to represent. A recurring concern is that micro-credentials risk proliferating without a shared unit of value, so that a badge issued by one provider cannot be compared with, or exchanged for, a badge issued by another (Moodie & Wheelahan, 2021). The response in the literature runs along two lines. One line anchors credentials to existing qualification frameworks and credit systems, extending recognition of prior learning logic into the micro scale (Raciti et al., 2024; Ogbeleakhu Aliu et al., 2026; Stone, 2016). The other line builds competence taxonomies that specify the granularity of the claim directly, whether as a personalised skills taxonomy for computing (Ward et al., 2021), as a validated sustainability competence framework (Martín-Ramos et al., 2025), or as a standardised digital competence framework for teachers (Kullaslahti et al., 2019). National ecosystem studies increasingly compare these arrangements across systems (Toledo-Navarrete et al., 2026; Yıldırım et al., 2025; Kicherova et al., 2026).

What the cluster rarely does is connect the credential to an occupational competency standard maintained outside the education system. The Finnish work on making vocational teacher competences visible through open badges (Kullaslahti et al., 2019) and the micro-competence framing developed for vocational education (Stankovski, 2025) are among the few contributions that treat the standard as a given external artefact rather than as something the institution defines. For vocational systems that already possess national occupational standards, this is the decisive difference, and it is precisely where the literature is thin.

***Assessment and quality assurance***

If a micro-credential is a claim about competence, its credibility rests on the evidence behind it. The assessment cluster is the second largest and contains the highest proportion of empirical work, with 12 of its 30 studies reporting empirical designs. Contributions here specify what counts as adequate evidence, how criteria are made explicit, and who is entitled to endorse the claim (Everhart et al., 2016; Ferguson & Whitelock, 2024). Discipline specific work is instructive. Laboratory skill development in chemistry using peer review combined with badges (Seery et al., 2017) and holistic skill badging across science programmes (Heaney et al., 2025) both demonstrate that badges can carry a defensible assessment load when the criteria are explicit and the evidence is performance based. Programme level evaluation is emerging as well, including the application of an established training evaluation model to a micro-credential programme (Tammeleht & Rajando, 2024) and retrospective analysis of an advanced computing micro-credential across several cohorts (Fishbein et al., 2024; Fishbein et al., 2025).

The persistent weakness is that assessment is generally institution internal. Assessors are academic staff, criteria are institutionally authored, and the workplace enters as a context for learning rather than as a site of assessment or a source of assessor authority. Work that proposes persona aligned assessment for postgraduate micro-credentials in emerging technologies (Tubino & Zaidi, 2026) and work on inclusive institution-wide assessment practice (O'neill & Lee, 2025) both illustrate the sophistication now available inside the institution, and simultaneously illustrate how little of it extends to industry assessors. In vocational systems where competence is certified by external bodies, this gap is structural rather than incidental.

***Credentialing technology and infrastructure***

The technology cluster is the most self-contained. It develops the machinery through which a credential becomes portable, verifiable, and tamper resistant, moving from early proposals for blockchain based credential management (Jirgensons & Kapenieks, 2018; Choi et al., 2019) toward decentralised frameworks for academic micro-credentials (Tanim et al., 2026), cloud native architectures integrated with learning management systems (Wang et al., 2026), and self-sovereign identity approaches to educational credentials (Herbke & Yildiz, 2022). Engineering concerns have matured accordingly: recent work addresses issuance at institutional scale through batching and off-chain storage (Andrian & Wiputra, 2026), and systematic reviews now assess the plausibility of decentralised education infrastructure as a whole (Razzaq et al., 2026).

Within this corpus the vocational absence is complete. None of the 20 Scopus indexed studies in the cluster is situated in a vocational setting, even though 11 of them address STEM subject matter. The infrastructure is therefore being designed against the requirements of universities, whose credential objects are courses and credits, rather than against the requirements of competency based systems, whose credential objects are units of occupational competence assessed against externally maintained standards. Studies that approach competence management directly, such as the Web 3.0 competence management approach (Francia et al., 2023), show that the alternative is technically feasible, and remain exceptions.

***Employability and labour market value***

The value of a credential is finally determined by whoever reads it. This cluster examines that judgement, and its findings are consistently more cautious than the policy rhetoric surrounding micro-credentials. Employer perception research finds that alternative credentials are read as signals whose weight depends on the reputation of the issuer and on the employer's prior familiarity with the instrument (Aerne & Bonoli, 2026), while systematic review evidence reports that stakeholder groups value micro-credentials for different and sometimes incompatible reasons (Varadarajan et al., 2023). Institutional strategy work links credential portfolios to employability outcomes (Alenezi et al., 2024; Ahmat et al., 2021), and a small number of studies model the relationship between micro-credentials and career awareness directly (Rullyana et al., 2026).

Two vocational contributions stand out. The synthesis of non-degree credentialing for STEM workforce development (Zinnah et al., 2025) is the closest the corpus comes to an evidence review on the focal question of this article, and the account of employer engagement in designing a stackable health sciences pathway (Reader et al., 2021) demonstrates a co-design mechanism that vocational systems could adopt directly. Beyond these, employer trust is discussed far more often than it is measured.

***Curriculum and instructional design and learner engagement***

The two remaining clusters are smaller but carry the practical detail. Curriculum work shows how credentials are constructed from modular units and how those units are delivered, including a fuzzy Delphi informed internet of things curriculum for community colleges (Techanamurthy et al., 2024), condensed skill building for the optics workforce (Parada et al., 2024), a full methodology linking curriculum development to training delivery and certification (Catenazzi et al., 2025), and a review of micro-learning in software engineering education (Parrales-Bravo, 2026). Learner engagement work, meanwhile, supplies the necessary corrective to enthusiasm. An early and widely cited assessment questioned whether digital badges deliver what is claimed for them (Roy & Clark, 2019), and subsequent studies report that learner value depends heavily on design and context rather than on the badge as such (van de Laar et al., 2024; Chandler & Perryman, 2023). Studies in secondary and outreach STEM settings show that badges can support participation among under-represented learners when the surrounding programme is deliberately designed for it (Mistretta et al., 2022; Burrows et al., 2022).

**A four layer recognition architecture**

The six thematic clusters reported above emerged inductively from the corpus. Read functionally, however, they are not independent concerns: each addresses one of a small number of problems that any competency recognition system must solve. Following the best fit framework logic set out in the method, the clusters were arranged deductively onto an a priori structure of four layers, so that the architecture is inductive in its categories and theoretically informed in its ordering. Layer 1 establishes what competence is claimed, drawing on the recognition architecture and frameworks cluster. Layer 2 establishes how the claim is evidenced, drawing on the assessment, curriculum, and engagement clusters. Layer 3 establishes how the claim is expressed and transported, drawing on the credentialing technology cluster. Layer 4 establishes whether the claim is honoured, drawing on the employability cluster. Quality assurance and governance run across all four layers rather than sitting within any one of them. Table 9 sets out this mapping in full so that the derivation is transparent and open to challenge, and Figure 6 presents the resulting architecture with the evidence density observed at each of the four layers.

Table 9. Derivation of the four layer architecture from the six thematic clusters

| **Layer** | **Recognition problem the layer solves** | **Thematic cluster(s) mapped (inductively derived)** | **n** | **STEM / TVET** |
|---|---|---|---|---|
| Layer 1: Competency standard and alignment | What competence is claimed | Recognition architecture and frameworks | 44 | 11 / 3 |
| Layer 2: Learning, evidence and assessment | How the claim is evidenced | Assessment and quality assurance; Curriculum and instructional design; Learner motivation and engagement | 57 | 20 / 7 |
| Layer 3: Credential and metadata | How the claim is expressed and transported | Credentialing technology and infrastructure | 20 | 11 / 0 |
| Layer 4: Recognition and labour market value | Whether the claim is honoured | Employability and labour market value | 17 | 3 / 3 |
| Cross-cutting: Quality assurance and governance | Trust maintained across the layers | Distributed across all clusters | n/a | n/a |
| Total | | | 138 | 45 / 13 |

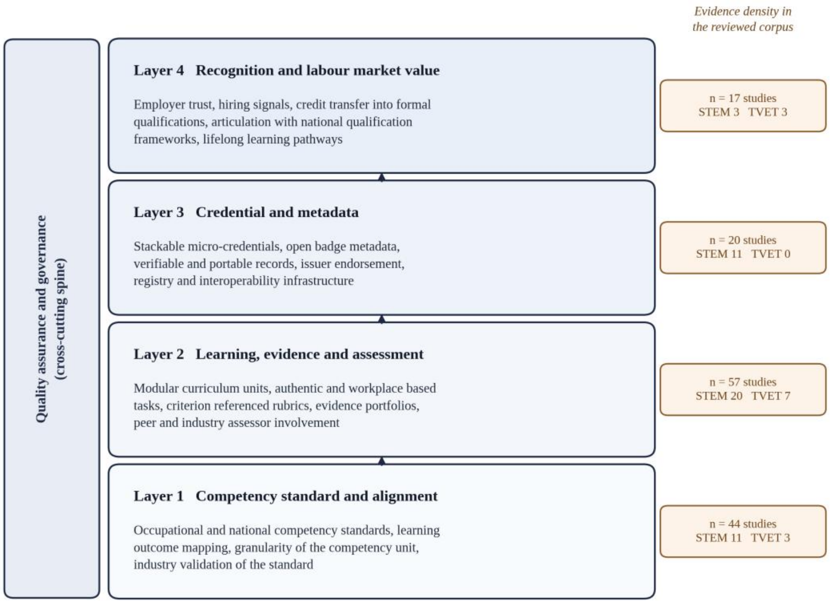


Figure 6. Four Layer Recognition Architecture Synthesised From the Reviewed Literature

The value of the arrangement is diagnostic. Layer 2 is the best populated, with 57 studies, of which 20 are STEM and 7 are vocational. Layer 1 follows with 44 studies, of which 11 are STEM and only 3 are vocational. Layer 3 contains 20 studies, 11 of them STEM and none vocational. Layer 4 is the thinnest with 17 studies, 3 STEM and 3 vocational. The vocational shortfall is therefore not uniform. It is mild at the level of learning and evidence, where vocational education has its own long tradition to draw on, and it is severe at exactly the two layers where vocational systems have the least room to improvise: the definition of the competency standard against which the credential is issued, and the infrastructure through which the credential is expressed and verified.

This unevenness explains a pattern otherwise difficult to interpret. Vocational institutions adopting micro-credentials can find substantial guidance on how to design and assess a modular unit, because that literature exists and transfers reasonably well. They will find much less guidance on how to bind that unit to a national occupational standard, and almost none on how to issue and verify it through infrastructure designed for competency units rather than for academic credits. The literature, in short, supports the middle of the recognition chain and leaves both ends underspecified for the vocational case.

**Evidence gaps and a research agenda**

Bringing the descriptive and thematic findings together yields five gaps, set out in Table 10 with the evidence that supports each and the research response it implies. The gaps are stated at the level of the field rather than as criticisms of individual studies, several of which explicitly acknowledge the same boundaries. Because the corpus is drawn from a single database, each gap should be read as a gap in the Scopus indexed evidence, that is, an

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absence of evidence within the mapped literature that motivates primary research, rather than as evidence that the practice itself is absent in the systems concerned.

Table 10. Evidence gap matrix and research agenda

| No | Gap | Evidence from this review | Research response implied |
|---|---|---|---|
| G1 | Vocational sector under-representation | 13 of 138 studies (9.4 percent) are situated in TVET or vocational settings, and only 7 (5.1 percent) combine a vocational setting with a STEM domain | Primary studies in vocational schools, polytechnics, and community colleges that report implementation and outcomes rather than intention, with sampling designed for the sector rather than borrowed from higher education |
| G2 | Missing link to occupational competency standards | Layer 1 contains 44 studies but only 3 vocational ones, and most anchor the credential to institutional learning outcomes rather than to externally maintained occupational standards | Design research that maps micro-credential units directly onto national competency standards and qualification framework levels, and that tests whether the mapping survives industry scrutiny |
| G3 | Infrastructure designed without vocational requirements | None of the 20 studies in the credentialing technology cluster is situated in a vocational setting, although 11 address STEM subject matter | Architecture studies in which the credential object is a unit of occupational competence and the issuer includes an external certification body, with interoperability tested against qualification framework metadata |
| G4 | Assessment authority confined to the institution | Assessment work is the most empirically developed cluster, yet workplace actors appear as learning contexts rather than as assessors or endorsers | Studies of shared assessment models in which industry assessors hold formal authority, including evidence on inter-assessor agreement and on the cost of maintaining such arrangements |
| G5 | Employer trust asserted rather than measured | Layer 4 is the thinnest layer with 17 studies, and employer perception is examined directly in only a small minority of them | Longitudinal and quasi-experimental designs that track credential holders into employment, together with employer side studies that measure how credential information actually enters hiring decisions |

A sixth observation concerns geography rather than substance. The two studies from Indonesia in a corpus of 138 stand in sharp disproportion to the size of the country's vocational system, and the same under-representation applies across much of Southeast Asia and Africa. Because recognition instruments are meaningful only within a specific qualification and labour market architecture, findings generated in European or North American systems cannot simply be imported. Systems that maintain national occupational standards and independent certification bodies constitute a distinctive and largely unstudied setting, and they may prove to be a more natural environment for competency based micro-credentials than the universities where the literature has so far concentrated.

**Implications for vocational education practice**

The recommendations in this section are interpretive rather than empirical: they extend the pattern of evidence described above into guidance for practice and should be read as the authors' reasoned inferences, not as findings established directly by the reviewed studies. Three implications follow for institutions that are being asked to adopt these instruments now, without waiting for the evidence base to fill. First, the unit of the credential should be taken from the occupational standard rather than from the course, because a credential defined by institutional delivery reproduces exactly the granularity problem it was meant to solve. Second, external assessors should be brought into the design of the evidence requirements at the outset rather than invited to endorse a finished product, following the co-design logic demonstrated in employer engaged pathway development (Reader et al., 2021) and in collaborative credential development between institutions and external organisations (Smith et al., 2025). Third, metadata should be treated as a policy decision rather than a technical one, since the fields that a credential carries determine whether it can later be mapped to a qualification framework level or recognised for credit (John & Hürten, 2025; Kiiskilä et al., 2023).

For the Indonesian setting in particular, the alignment opportunity is unusually direct. A national competency standard system already defines the competency units that Layer 1 of the architecture requires, and independent certification bodies already exercise the external assessment authority that Layer 4 requires for employer trust. What is missing is the connective work at Layer 3, namely a credential and metadata design that can carry a competency unit identifier, an assessor identity, and a qualification framework level in a form that both education providers and employers can verify. That is a tractable design problem, and it is one on which the international literature currently offers very little guidance.

**Limitations**

Four limitations qualify these findings. The review draws on a single database, so scholarship indexed elsewhere, including much regional vocational research published in national languages, is absent by construction; the exclusion of two non-English records illustrates the boundary. Screening and coding were performed on bibliographic metadata rather than full texts, which is adequate for mapping a field but cannot capture methodological quality, and no formal risk of bias appraisal was conducted. Coding applied a rule based scheme followed by manual adjudication of vocational and borderline assignments, but independent double coding was not performed, so no inter-rater reliability statistic is available. Finally, the corpus is heavily open access, at 95.7 percent, and the 2026 figures are partial because the search was executed in August of that year. These constraints affect the precision of the percentages reported here, but they do not plausibly account for a vocational share of under 10 percent or for the absence of any vocational study among the infrastructure studies in this corpus.

## CONCLUSION

This systematic mapping review examined 138 Scopus indexed studies published between 2014 and 2026 to chart how the literature on micro-credentials and digital badges addresses competency recognition, and to locate that work within the settings where technical skills are actually formed. Its principal contribution is not a further count of publications but a functional architecture: the six thematic clusters that emerged inductively from the corpus were arranged onto four layers that any recognition system must resolve, namely the definition of the competency standard, the generation of learning evidence, the expression of the claim through credential and metadata, and its honouring in the labour market, with quality assurance and governance running across all four. Read through this architecture, the field is neither empty nor mature but populated unevenly: STEM and computing disciplines account for the largest share of studies (45 of 138), technical and vocational education and training is represented sparsely (13), and the intersection of the two is thinner still (7).

The diagnostic value of the architecture lies in where the evidence thins. The corpus is best populated at the middle of the recognition chain, where learning is designed and assessed, and least populated at its two ends, where the competency standard is defined and where the credential is expressed and verified through dedicated infrastructure; the vocational shortfall is sharpest at exactly these two points, precisely where vocational systems have the least room to improvise. These patterns should be read with care. Because the corpus is drawn from a single database and coded at the level of bibliographic metadata, and because no formal quality or risk of bias appraisal was undertaken, thin and empty cells are best understood as an absence of evidence in the indexed literature rather than as proof that the underlying practice is absent. On that understanding, the review sets out a research agenda that connects credential design to national competency standards, to workplace based assessment, and to employer trust, and it invites vocational systems, including Indonesia's, to treat the definition of standards and the building of credentialing infrastructure as the parts of the recognition problem most in need of evidence.

## SUGGESTIONS

Four directions follow for subsequent research. Empirical work in vocational settings should be prioritised over further conceptual argument, with designs that report implementation and outcomes in vocational schools, polytechnics, and community colleges rather than institutional intentions. Design based research should test the direct mapping of micro-credential units onto national occupational competency standards and qualification framework levels, treating the standard as an external artefact that the credential must satisfy rather than as something the provider defines. Architecture research should develop credential and metadata schemas in which the unit is a competency unit and the issuing authority includes an external certification body, since none of the infrastructure studies reviewed here addresses that configuration. Finally, outcome research should move employer trust from assertion to measurement, through longitudinal tracking of credential holders and employer side studies of how credential information enters hiring decisions.

Two methodological suggestions apply to reviews in this area specifically. Future syntheses should search beyond a single database and should include regional and non-English sources, because the vocational literature is disproportionately published in national venues and is therefore systematically invisible in Scopus based corpora. Reviews should also report the sector and domain composition of their corpus explicitly, since aggregate claims about micro-credential effectiveness drawn from predominantly higher education samples are routinely read as claims about education in general.

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