Thematic mapping of competence-based education and training research through direct citation network analysis and topic modelling with latent semantic analysis

Received 17 March 2025
Revised 17 October 2025
Accepted 8 November 2025

Joonas Mannonen
Finnish Institute for Educational Research, University of Jyväskylä, Jyväskylä, Finland
Felipe Urrutia
Center for Advanced Research on Education, Institute of Education, University of Chile, Santiago, Chile
Raija Hämäläinen
Department of Education, Faculty of Education and Psychology, University of Jyväskylä, Jyväskylä, Finland
Roberto Araya
Center for Advanced Research on Education, Institute of Education, University of Chile, Santiago, Chile
Sami Lehesvuori
Department of Education, Faculty of Education and Psychology, University of Jyväskylä, Jyväskylä, Finland, and
Danial Hooshyar
School of Digital Technologies, Tallinn University, Tallinn, Estonia; Faculty of Education and Psychology, University of Jyväskylä, Jyväskylä, Finland and Faculty of Information Technology, University of Jyväskylä, Jyväskylä, Finland

Abstract

Purpose – The purpose of this study is to provide researchers, policymakers and practitioners with a state-of-the-art snapshot of the competence-based education and training (CBET) research domain by identifying its main research streams, as well as its dominant and under-explored research areas.

Design/methodology/approach – We employed direct citation network analysis to examine the intellectual structure of CBET research and identify its main research streams across 1,090 journal articles. To further explore the themes within these streams, we applied topic modelling with latent semantic analysis.

Findings – CBET is a fragmented research domain, based on the citation relationships among articles and the diversity of journals in which they have been published. Its core consisted of 231 articles, from which three main

Funding: This research was partly funded by the Research Council of Finland (grant numbers 353325 and 372920), ANID/PIA/Basal Funds for Centers of Excellence AFB240004 and ANID Exploración 13240075.

Education + Training
Vol. 68 No. 10, 2026
pp. 1-16
Emerald Publishing Limited
e-ISSN: 1758-6127
p-ISSN: 0040-0912
DOI 10.1108/ET-03-2025-0161

research streams emerged: the Higher Education Stream, the Vocational and Professional Education Stream, and the General Education Stream. We present six dominant topics covered by the research streams and highlight the need for future studies that transcend educational levels.

Originality/value – We employ novel methods to provide researchers, policymakers and practitioners with the first topical overview of CBET research.

Keywords Competence-based education, Competence-based training, Key competences, Topic modelling, Latent semantic analysis

Paper type Literature review

1. Introduction

Competence-based education and training (CBET) is a debated educational paradigm that has transformed educational policy and practice from early childhood education to adult and continuing education in numerous countries (Morselli, 2024; Saadvandi *et al*., 2023). While the number of primary studies about CBET has increased exponentially over the past decades, providing stakeholders with much needed evidence about its implications and best practices, the number of secondary studies remains severely limited. As a result, little is known about the topics that CBET research has been concerned with or should be more concerned with in the future. As secondary studies are an essential part of the scientific process and help steer future research, policymaking, and practice, we recognize this as a clear gap in CBET literature (Kitchenham *et al*., 2011; Peterson *et al*., 2017).

Reviewing CBET research, however, is a challenging task because there is no consensus on what exactly makes education "competence-based". CBET approaches have been implemented in diverse ways around the world, and it has become an umbrella concept for different ideas and practices (Wesselink and Giaffredo, 2015). Several studies have addressed this phenomenon (e.g. Mulder *et al*., 2007). In the beginning of the millennium, Le Deist and Winterton (2005) identified multiple competence approaches that had evolved largely independently in different parts of Europe and the US. Since then, national education policies have been increasingly subject to international influences, and CBET approaches have been introduced in many new countries. This, however, has not necessarily meant less variation in interpretation. Nordin and Sundberg (2021) demonstrated how key competences, as defined by the European Union, were implemented across nation states through complex political processes—leading to diverse interpretations despite originating from a shared framework.

Educational research offers no easy answers either, as scholars have long highlighted conceptual and terminological inconsistencies surrounding CBET. For example, in their review of CBET definitions within general education studies, Tahirsylaj and Sundberg (2020) found that a significant number of these studies failed to explicitly define the concept. Brauer (2021) reviewed competence-oriented education studies in higher education and demonstrated how ambiguous terminology and inconsistent language remain significant challenges.

Perhaps the most refined definition of CBET originates from the model of comprehensive CBET developed in the Netherlands (e.g. Saadvandi *et al*., 2023; van Griethuijsen *et al*., 2020). In this model, researchers characterize vocational education as 'competence-based' when certain key principles are present in educational practice. They stress the importance of defining the competences underpinning the study program in close collaboration with field practitioners, and advocate for organizing the curriculum around vocational core problems. The model goes on to outline the types of learning, instruction, and assessment that foster competence development. These include assessment throughout all stages of the learning process, authentic and collaborative learning experiences, a gradual shift in responsibility for the learning process from teachers to students, and the dual role of teachers as both experts and coaches who adapt their guidance to individual student needs (van Griethuijsen *et al*., 2020). From this perspective, CBET is not a binary concept of either-or but rather a continuum reflecting varying degrees of implementation of these principles.

Greater clarity on CBET emerges through the definitions of competence and the approaches used to study it. Despite considerable variation, two elements have remained relatively consistent across definitions in educational research over the past 2 decades (e.g. Wijnia *et al.*, 2016). First, competence is an integrated whole comprising various components—such as knowledge, skills, and attitudes—that relate to different domains of human functioning, including cognitive, affective, motoric, and social aspects (e.g. Halász and Michel, 2011). Second, competence is applicable in real-world contexts and, depending on the definition, facilitates task completion, problem-solving, goal achievement, information processing, or value creation (e.g. Tiana *et al.*, 2011).

Regarding how competence has been studied, Mulder *et al.* (2007) identified three main traditions: behaviourist, generic, and cognitive. The behaviourist approach centres on observing effective job performers and analysing how they differ from others—defining competence through demonstration, observation, and performance assessment. The generic approach, by contrast, seeks to identify common individual traits that account for variations in performance, typically through statistical analysis. Studies on the five personality dimensions and international large-scale assessments exemplify this tradition (Mulder *et al.*, 2007). Lastly, the cognitive approach emphasizes the mental resources required for knowledge acquisition and effective performance, often drawing on information-processing models, psychometric models of human intelligence, and social-constructivist theories of learning.

No reviews have traced the evolution of these approaches to a later date. However, behaviourist approaches to competence have long faced criticism from educational researchers for their inability to capture the complexity of human development and unique sociocultural contexts (e.g. Hyland, 1993). In contrast, the latter two approaches appear to have gained momentum, as reflected in the growing significance of international large-scale assessments and heightened interest in the social and emotional dimensions of competence.

Above, we have presented a brief overview of the research domain targeted by this review. For research domains that are broad, heterogeneous, or have not yet been extensively reviewed—such as CBET research—several methodologists recommend conducting scoping reviews or mapping studies as the most advantageous initial step for exploring the landscape (Kitchenham *et al.*, 2011; Peterson *et al.*, 2017). One of the primary aims of these studies is to offer a comprehensive overview of a research domain, which other scholars can then use to formulate their own research questions or conduct more focused, in-depth reviews on specific topics.

To that end, this study aims to offer researchers, policymakers, and practitioners an accessible overview of the CBET research domain, including both its areas of focus and those it has yet to explore. Acknowledging the diversity of CBET approaches outlined above, we adopt a broad scope—considering any study that specifically addresses competence-based education, training, curriculum, or key competences as part of CBET research—in order to capture the full range of related topics.

The massive growth of academic literature available in digital format, however, calls for the adoption of novel review methodologies suitable for the analysis of large datasets (Basilio *et al.*, 2022). To complement traditional focused literature reviews, advanced bibliometric and text-mining methods have been increasingly used in educational research to identify trends in large bodies of academic literature. For example, Fellnhofer (2019) used text-mining techniques to develop a taxonomy of entrepreneurship education research. Shen and Ho (2020) applied direct citation network analysis (DCNA) and topic modelling with latent semantic analysis (LSA) to present the historical development of technology-enhanced learning research. These methods offer researchers an efficient means of analysing large datasets, thus enabling the inclusion of more primary studies for review than would be possible with manual means (Chen *et al.*, 2020).

In this study, we begin by using DCNA to cluster CBET articles based on their citation relationships, allowing us to examine the intellectual structure of CBET research and identify its main research streams. Next, we explore the topics that the CBET research streams have

covered by adopting topic modelling with LSA, a natural language processing technique that relies on powerful statistical analyses to extract and represent semantic structures of large textual datasets (Kwon *et al.*, 2017). Topic modelling presumes that textual data include hidden semantic patterns, called topics, that may be common across different documents but obscured by word choice (Basilio *et al.*, 2021; Kwon *et al.*, 2017). These topics, in turn, can be used to automatically cluster articles based on the similarity of their content (Chen *et al.*, 2020). Despite the promising adoption of topic modelling with LSA in other educational research domains, to the best of our knowledge, no such attempts have been made in CBET research to date. We put forth the following research questions:

RQ1. What are the main streams of CBET research?

RQ2. What kinds of topics have the main CBET research streams covered?

The remainder of the manuscript is structured as follows: Section 2 details the methodology, including research design, search strategy (2.1), citation analysis (2.2), and topic modelling (2.3). Section 3 presents the results—three main streams of CBET research and six topics per stream. Section 4 discusses key findings and future directions, while Section 5 outlines limitations relevant to interpreting the results.

2. Methodology

Figure 1 displays our research design. In the data acquisition phase, we retrieved 1,090 journal articles with CBET-related key phrases from the Scopus database in October 2023. Next, we conducted direct citation network analysis to map, cluster, and visualize the main streams of CBET research (RQ1). Finally, we employed topic modelling with LSA for each of the research streams to identify the topics on which they have focused (RQ2).

2.1 Search strategy

We selected Elsevier's Scopus database for article retrieval due to its extensive coverage of social science journals, which makes it particularly suitable for citation analysis (e.g. Mongeon and Paul-Hus, 2016). Upon initial trials of databases with CBET-related key phrases, we found that Scopus also has a rich collection of CBET articles compared to other databases (for more explanation of the choice of database, see Section 5). We found the query string adopted by Tahirsylaj and Sundberg (2020) in their CBET review to be the most comprehensive to date; however, we extended it further with "competence-based training" to include forms of education that do not lead to formal qualifications:

TITLE-ABS-KEY("competence-based education" OR "competence-based training" OR "competence-based curricul*" OR "key competenc*")

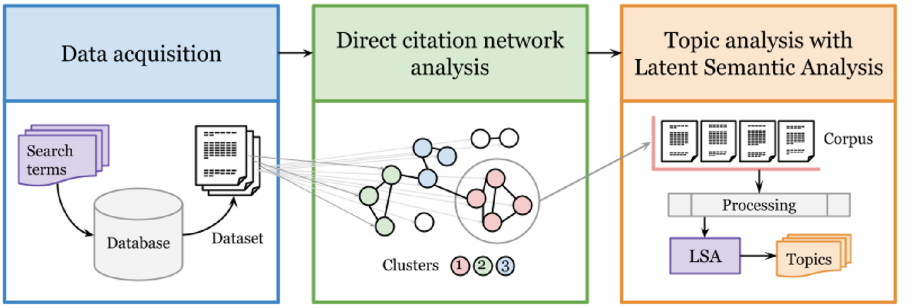

Figure 1. Methodology diagram. Source: Authors' own work

With the above query, documents containing at least one of the key phrases in the title, abstract, or keywords were included in the search results. We then applied four inclusion criteria to the retrieved documents: (1) language: English; (2) source: journal; (3) document type: article, review; and (4) field: social sciences. This query yielded a sample of 1,090 CBET articles in October 2023 (Supplementary material 1).

2.2 Direct citation network analysis

DCNA is a method that utilizes the reference lists of articles to identify research fronts within scientific literature (e.g. Shen and Ho, 2020). In the analysis, two articles are linked if one of them has directly cited the other. The first application of DCNA, mapping, projects the network of articles in two dimensions. The second application, clustering, is an unsupervised learning technique that groups similar articles. The output of the analysis is a graph called a direct citation network, in which each node represents an article (denoted by the name of the first author and publication year) and the lines between the nodes, the edges, whether an article is cited by another in the network (Kleminski *et al.*, 2022). Node size is proportional to the number of adjacent edges—larger nodes indicate articles that are more extensively linked to others within the network. The distances between the nodes are proportional to their association strength.

To conduct the analysis, we employed the widely adopted and well-documented VOSviewer tool (van Eck and Waltman, 2009; Waltman *et al.*, 2010; version 1.6.19; https://www.vosviewer.com/), which uses the procedures described below.

In a network of n articles, $c_{\{ij\}}$ is a variable that indicates if article i is connected to article j in the direct citation network (1 if connected and 0 if otherwise; Waltman *et al.*, 2010). The matrix with the coefficients $c_{\{ij\}}$ is called the adjacency matrix of the network. To map or cluster the articles of the network, it is sufficient to minimize the function

$$V(x_1, \ldots, x_n) = \sum_{i<j} s_{ij} d_{ij}^2 - \sum_{i<j} d_{ij},$$

where sij is the strength between article i and article j (e.g. $sij = cij$), and dij is the distance between article i and article j, the form of which depends on whether mapping or clustering is intended. To calculate the distance in the first case, VOSviewer uses the Euclidean norm, i.e. $d_{\{ij\}} = \left|x_i - x_j\right|^2$. For the second case, the distance was a weighted indicator that was 0 if the cluster of article i was the same as that of article j (i.e. $x_i = x_j$) and $\gamma - 1$ if otherwise. The positive constant γ, usually called the resolution, allows the number of clusters to increase as its value increases.

To find the largest connected component in the direct citation network (i.e. the subgraph with the largest number of articles), we used clustering without edge weighting (no normalization). This means that the strength between the articles corresponds to the values of the adjacency matrix of the network, i.e. $s_{ij} = c_{ij}$. To analyse the largest connected component and cluster its articles into well-defined groups for further topic analysis, we normalized the clustering of the edges with the association strength technique (van Eck and Waltman, 2009). This allows articles that are cited more often to attract more articles that cite them, as opposed to those that do not. The strength between nodes is then defined as:

$$s_{ij} = \frac{2Mc_{ij}}{c_i c_j}, \text{ where } M = \frac{1}{2}\sum_k c_k \text{ with } c_i = \sum_{i \neq k} c_{ik}.$$

After determining the clusters using DCNA, we conducted a qualitative screening of the articles within each cluster and provided the clusters with appropriate names to identify the main streams of CBET research (RQ1).

2.3 Topic modelling with LSA

In topic modelling with LSA, topics are first extracted from the entire dataset (corpus) by identifying groups of terms that co-occur in the articles. Subsequently, each article receives a strength rating for its association with each topic, with articles being allowed to encompass numerous corpus-wide topics. These topics, in turn, may apply to numerous articles (Chen *et al.*, 2020). The process of topic modelling with LSA involves several manual steps by researchers concerning data processing and the interpretation of results (Kwon *et al.*, 2017).

First, we assumed that each article is a single large text: a concatenation of its title, abstract, and keywords. Next, we preprocessed the articles by applying seven text-mining filters, which have been shown to improve results in previous studies: removal of punctuation symbols, stop-words, and specific words that carry no relevant meaning, replacement or simplification of some key phrases by a single text unit, conversion of tokens to lowercase, lemmatization of tokens, and expansion of abbreviations (Sehra *et al.*, 2017). After preprocessing the articles, we decomposed the text into minimal units (n-grams) of words to form a document–term matrix. We used uni-grams (or 1-g) to segment the text while also considering bi-grams (or 2-g), as they may produce more meaningful terms than uni-grams. We discarded n-grams with n greater than 2 because of their potential to weaken the performance of the analysis (Hussein, 2015). We performed the preprocessing and tokenization of the data using the spaCy library (https://spacy.io/), a widely used tool for natural language processing problems.

Next, we used the resulting document–term matrix to represent the corpus. The matrix coefficients (tf_{ij}) correspond to the number of times term *i* occurs in document *j*, representing a bag-of-words (bow) representation. To take into account the importance of a term occurring throughout the corpus, we updated the document–term matrix with the term frequency–inverse document frequency (*tf-idf*) matrix. Unlike in the bow representation, the tf_{ij} value is weighted by the logarithm of the inverse of the probability of finding term *i* in any document in the corpus (Shen and Ho, 2020). In effect, the matrix *tf-idf* is given by:

$$A_{ij}^{\mathrm{tf-idf}} = \mathrm{tf}_{ij} \cdot \log\left(\frac{n}{\mathrm{df}_i}\right),$$

where df_i is the number of documents in the corpus in which term *i* occurs and *n* is the size of the corpus. To construct the tf-idf matrix, we used the open-source Python library Gensim (tfidfmodel class, models module; https://radimrehurek.com/gensim/models/tfidfmodel.html).

We performed the analysis using singular value decomposition (SVD). The SVD of a matrix *M* of dimension *mxn* is a factorization of the form *UΣV^T*, where *Σ* is an *rxr* matrix, *U is* an *mxr* matrix, *V is* an *nxr* matrix, and *r is* the rank of *M*. In its compact version, *Σ* is a diagonal matrix with the roots of the eigenvalues of *M* ordered from largest to smallest, *U* a matrix with the eigenvectors of *MMT*, and *V* a matrix with those of *MTM* in the same order as the assignment of the coefficients of *Σ*. In the case of a *tf-idf* matrix associated with the corpus, the *Σ* matrix is called *topic strength*, while the *U* and *V* matrices are called *term–topic* and *document–topic*, respectively. The *U* and *V* matrices store the projections of each term and document on the *r* topics (in the same order). The first *k* singular values with the largest contributions in the *Σ* matrix can be chosen as topics by truncating the matrix up to the first *k* rows and columns and truncating the *U* and *V* matrices accordingly. This creates an approximation of the *tf-idf* matrix, where $k = r$ completely recovers the original matrix. To compute the SVD of the tf-idf matrix, we used Gensim again (lsimodel class, models module; https://radimrehurek.com/gensim/models/lsimodel.html).

To determine the optimal number of topics, we used the elbow of eigenvalues method, which consists of plotting the eigenvalues of *M* as a function of their relative size (Kulkarni *et al.*, 2014). The elbow of the graph is identified when the eigenvalues stop decreasing rapidly and start decreasing slowly, indicating the smallest number of topics where the contribution made by adding another topic is marginal. To compute the eigenvalues, we used the open-source Python

library for mathematics, science, and engineering called SciPy (eigs function, sparse.linalg module; https://docs.scipy.org/doc/scipy/reference/generated/scipy.sparse.linalg.eigs.html).

After the appropriate number of *k*-topics was selected, the truncated *U* and *V* matrices were left. To interpret the chosen topics, we used minimum proximity cutoffs to determine whether a term belonged to a topic. Specifically, for a topic *t* with cutoff ϕ_t, the term *i* belongs to the topic if and only if its proximity to topic *t* is greater than the minimum cutoff, i.e. $|U_{ti}| \geq \phi_t$ (Sehra *et al.*, 2017). The minimum cutoff ϕ_t is calculated as the mean plus one standard deviation of the absolute values of the *t-th* column of *U* (Shen and Ho, 2020). To determine the documents that belong to a particular topic, we used the document–term matrix with the *tf-idf* weights of the terms in the topic. The normalized version of the proximities of each document (denoted by *W*) is a row-weighted version of the matrix, where each row adds up to 1 (Shen and Ho, 2020). We then assigned the documents to a topic if the $\overline{W}_{jt}$ value was greater than the minimum cutoff θ_t, which is calculated as the mean plus one standard deviation of the values in the topic's column of $\overline{W}$ (Shen and Ho, 2020). After identifying the topics, we provided them with appropriate names by qualitatively screening their articles and top terms.

3. Results

CBET emerges as a fragmented research domain based on our analysis. The DCNA revealed that, across the entire sample, each article was linked to only one other article on average (average edge number: 0.98). This fragmentation is further reflected in the journal data, which showed that only two journals contained more than 20 CBET-related articles (*Supplementary material 1*). Overall, CBET publications were dispersed across a range of general and field-specific education journals, with no single journal dedicated exclusively to CBET.

The largest citation-linked group of CBET articles comprised 231 articles. Within this group, the total number of edges was 984, with an average of 4.26 edges per article and a standard deviation of 6.39. Notably, 92.13% of all citation links in the sample were concentrated within this group. The remaining articles were either isolated or clustered in small groups that had no citation links to the main group. From this point forward, our analysis focuses on the largest connected component, which emerged as the core of CBET research.

Clustering within the largest connected group of articles revealed three main streams of CBET research (Figure 2). Of the 231 articles in this group, 108, 66, and 57 were assigned to Clusters 1, 2, and 3, respectively. Cluster 1 (red) primarily focused on higher education; Cluster 2 (green) on vocational and professional education; and Cluster 3 (blue) on general education, encompassing both primary and secondary levels. Accordingly, we refer to these clusters as the Higher Education (HE) Stream, the Vocational and Professional Education (VPE) Stream, and the General Education (GE) Stream. Complete lists of articles for each research stream, along with their total citation counts and citations within the CBET network, are provided in Supplementary material 1.

Table 1 presents the author-named topics, examples of top terms (and total number of terms) by topic, and the number of CBET articles associated with each topic. For a full list of articles by topic, see Supplementary material 1.

In the HE Stream, *Topic 1* focused on sustainability key competences. For example, the studies conceptualized sustainability key competences based on stakeholder perspectives (Eizaguirre *et al.*, 2019) and studied how they have been implemented in curricula (González-Salamanca *et al.*, 2020) and what kind of pedagogies support their development (Redman *et al.*, 2021). *Topic 2* examined competence assessment and evaluation. The articles introduced methodologies for the assessment of key competences (Remington-Doucette *et al.*, 2013) and professional competences (e.g. Mahfud *et al.*, 2020). Furthermore, they presented quality criteria and methods to be used in CBET evaluation (e.g. Bergsmann *et al.*, 2015).

Topic 3 pertained to real-world learning activities to develop students' sustainability key competences. The studies assessed student learning in university courses and programs that employed different real-world learning activities, such as experience-based, problem-based,

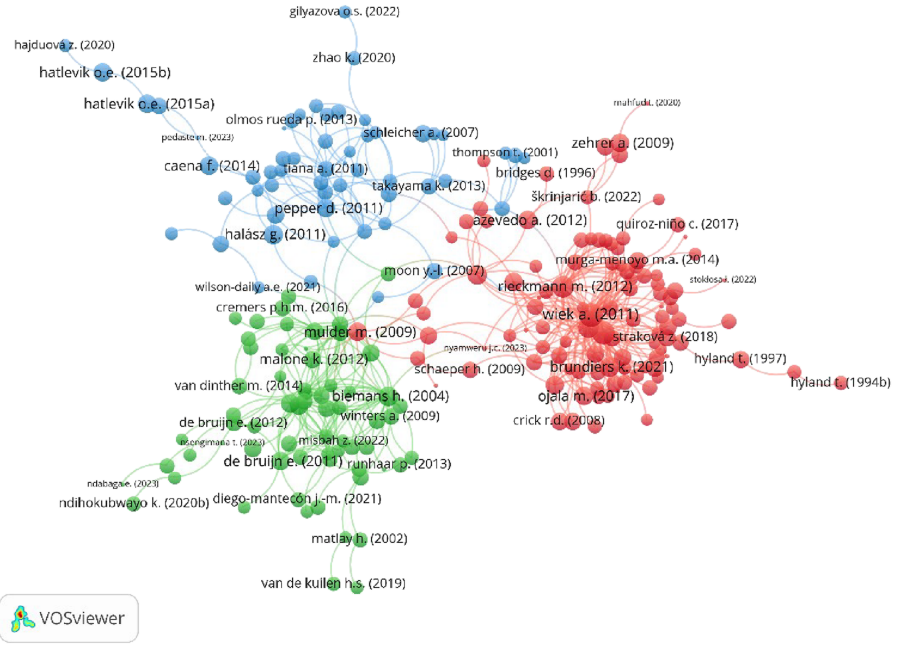

Figure 2. The main streams of competence-based education and training research. Source: VOSviewer

or project-based learning (e.g. Birdman *et al.*, 2022; Konrad *et al.*, 2020). *Topic 4* focused on the development of educational programs in different fields, such as agriculture (Migliorini and Lieblein, 2016), business (Siirilä *et al.*, 2022), and education for sustainable development (Seo *et al.*, 2020).

Topic 5 examined competences that facilitate graduate employability, job performance, and career development. Researchers have conducted graduate and employer surveys in the fields of public health, tourism, and business to identify the most relevant professional competences in these fields (e.g. Azevedo *et al.*, 2012; Zehrer and Mössenlechner, 2009). In addition, one study focused on the core coaching competences of school-to-work transition coaches and teachers (van der Baan *et al.*, 2022). *Topic 6* pertained to the facilitation of the United Nations' Sustainable Development Goals. For example, researchers have examined the topic from the perspectives of curriculum (Salovaara *et al.*, 2020), student perceptions (Alm *et al.*, 2022), and teaching and learning (Alm *et al.*, 2021).

In the VPE Stream, *Topic 1* focused on stakeholder perspectives on CBET implementation. Researchers have studied the experiences and practices of students, student teachers, teachers, teacher educators, and employers (e.g. Brauer, 2021; Morselli, 2018). *Topic 2* examined students' self-efficacy and perceived competence. Researchers have developed and tested self-report instruments for generic and professional competences (e.g. Khaled *et al.*, 2014) and studied how students' perceptions of competence-based assessment were associated with their self-efficacy and learning outcomes (e.g. van Dinther *et al.*, 2015).

Topic 3 discussed the implementation of competence-based curricula in Sub-Saharan Africa, particularly Rwanda. For example, the articles examined literature on the state of implementation (Nsengimana *et al.*, 2020), educational policy adoption mechanisms (van de Kuilen *et al.*, 2019), and teaching and learning in schools where CBET had been implemented (Ndihokubwayo *et al.*, 2020). *Topic 4* pertained to teachers' team learning. Researchers have engaged teachers, teacher team managers, and students to determine what makes teacher teams

Table 1. Competence-based education and training research topics by research stream with examples of top terms and descriptive statistics by topic

Research stream	Topic no.	Topic name	Examples of top terms (total no. of terms)	No. of articles
HE	1	Sustainability key competences	sustainable development, program, student, learning, education sustainable (887)	12
	2	Assessment and evaluation	assessment, competence assessment, assessment program, self-evaluation, quality (1,170)	18
	3	Real-world learning activities	project base, course, program, qualification, education training (1,247)	16
	4	Educational program development	quality, vocational, evaluation, criterion, standard (878)	11
	5	Competences to facilitate education-to-work transitions	public health, employer, health professional, graduate, enter (525)	7
	6	The United Nation's Sustainable Development Goals	development goal, teacher, teacher education, system think, science education (1,135)	14
VPE	1	Stakeholder perspectives	education training, vocational education, teacher, implementation, student (520)	10
	2	Student self-efficacy	self-efficacy, student self, assessment characteristic, student teacher, student perception (399)	4
	3	Competence-based curricula in Sub-Saharan Africa	base curriculum, education training, curriculum implementation, capacity, science teacher (631)	9
	4	Teacher team learning	teacher team, team learning, student satisfaction, team effectiveness, task interdependence (500)	3
	5	Teacher behaviour	behaviour, teacher interpersonal, interpersonal behaviour, student motivation, base vocational (415)	7
	6	Teacher professional development needs	human resource, resource management, resource policy, professional development, development activity (616)	6
GE	1	Key competences as a European educational policy trend	teacher, policy, student, base curriculum, key competence (527)	12
	2	Digital competence	digital, digital competence, student digital, information, digital literacy (527)	6
	3	Key competences in Spain	model, primary education, teacher perception, primary school, questionnaire (812)	7
	4	Experiences and challenges of implementation	base curriculum, case study, secondary school, classroom, framing (623)	6
	5	National recontextualization of key competences	critical thinking, Kosovo, member states, key competence, transnational (761)	6
	6	Supporting young people's learning of key competences	policy, European, young people, formal, child (704)	9

Source(s): Authors' own work

effective (Truijen *et al.*, 2013) and how the level of CBET implementation, teacher team learning and team characteristics, and student satisfaction are associated (van Griethuijsen *et al.*, 2020; Wijnia *et al.*, 2016).

Topic 5 examined teacher behaviour and its associations with learning and the level of CBET implementation (e.g. De Bruijn, 2012; Misbah *et al.*, 2022). *Topic 6* discussed the roles of school management and teachers in implementing CBET. For example, researchers have

examined schools' human resource policies and teachers' professional development activities and needs (e.g. Runhaar and Sanders, 2013; Seezink and Poell, 2011).

Topic 1 of the GE Stream reviewed the European educational policy trend of implementing key competences for lifelong learning. Researchers have studied policy documents (e.g. Clément, 2021), curricula (e.g. Palsa and Mertala, 2022), and literature (e.g. Tahirsylaj and Sundberg, 2020) on the extent and implications of this trend in European countries. *Topic 2* introduced digital competence as a key competence for lifelong learning in Europe. Researchers have conceptualized digital competence (e.g. Guitert *et al.*, 2021) and developed tests for its assessment (e.g. Hatlevik *et al.*, 2015; Pedaste *et al.*, 2023).

Topic 3 focused on key competences for lifelong learning in Spain. For example, the articles examined teacher perceptions on the inclusion of key competences in curricula (García-López *et al.*, 2020; Meroño *et al.*, 2019) and the teaching competences most essential for developing students' key competences (De-Juanas Oliva *et al.*, 2016). *Topic 4* was related to the experiences of and challenges faced by schools in implementing competence-based curricula. The articles focused on multiple aspects of CBET implementation, such as curriculum planning (Downey *et al.*, 2013) and teaching and learning (Alkandari, 2023; Byrne *et al.*, 2013).

Topic 5 focused on how transnational key competences for lifelong learning have been recontextualized nationally in European countries. Researchers have analysed implementation strategies by reviewing curriculum and policy documents, identified challenges, and provided recommendations (e.g. Halász and Michel, 2011; Tiana *et al.*, 2011). The articles in *Topic 6* pertained to young people's learning of key competences from a well-being and social participation perspective. Researchers have covered children's well-being and the core capacities that support their learning of key competences (Gordon and O'Toole, 2015), socially excluded young people's nonformal learning of key competences (Ravenscroft *et al.*, 2020) and young school dropouts' perceptions of their mastery of key competences (Olmos Rueda and Mas Torelló, 2013).

4. Discussion, conclusions, and implications

The aim of this article was to provide researchers, policymakers, and practitioners with an overview of the CBET research domain. We began by examining the intellectual structure of CBET research using DCNA. From a sample of 1,090 CBET articles, we identified a group of 231 interconnected publications that accounted for nearly all citation links within the dataset. The average number of citation links across the entire sample was notably low (0.98), indicating that CBET is a highly fragmented research domain.

This fragmentation was further reflected in the dispersion of CBET research across both field-specific and generic education journals, with no journal dedicated exclusively to CBET. Such dispersion likely contributes to the absence of consistent, established conceptualization and terminology noted in previous studies (Brauer, 2021; Tahirsylaj and Sundberg, 2020). Without a shared set of foundational works or commonly read journals, conceptual and terminological inconsistencies are likely to remain a challenge in the future. The research domain would benefit from a dedicated journal focused on the conceptualization and implementation of CBET, one that welcomes contributions from a wide range of practical contexts. By supporting educational practice, such a journal could have a significant societal impact, as CBET approaches influence the learning of millions of students worldwide.

In the next phase, we applied clustering to identify the main streams of CBET research within the core group of articles. Three distinct research streams emerged: the HE Stream, the VPE Stream, and the GE Stream. In other words, CBET research clustered according to the types of education—i.e. practical contexts—on which the studies focused.

In other educational research domains where similar methodologies have been used, articles have tended to cluster around shared phenomena or theoretical schools of thought (e.g. Shen and Ho, 2020). While it is somewhat intuitive that studies would build upon others situated in similar educational contexts, one might expect that the core question of how to

structure education and training to effectively support competence development would transcend specific contexts. One possible explanation is that CBET, as a research domain, has not yet developed a diverse range of theoretical perspectives or schools of thought.

In the final phase, we identified six dominant topics within each research stream through topic analysis. A key conclusion is that these topics vary significantly across the streams, with minimal overlap. The HE Stream focused predominantly on sustainability key competences, the VPE Stream explored teacher and student experiences with the practical implementation of CBET, and the GE Stream focused on curriculum and educational policy. Notably, each of these topics was entirely absent from the other two streams.

While it is understandable that certain topics may be absent in specific practical contexts—for example, employability competences in GE—future CBET research would benefit from cross-stream collaborations that transcend these contextual boundaries. For example, since the success of any educational reform fundamentally depends on teachers and learners, we recommend that future studies examine their experiences in HE and GE to identify barriers to practical implementation. In doing so, researchers may find valuable insights and collaborations in the VPE Stream, which already has a long history of studying this topic.

Finally, because cross-curricular key competences are intended as overarching goals that span entire education systems and necessitate collaboration between different types and levels of education (e.g. European Council, 2018), we recommend that future studies examine how these competences are developed as a continuum across entire education systems. Such studies would complement existing research focused on specific education levels and foster stronger connections between them in the development of key competences. For this, researchers may want to draw on the HE and GE Streams, where specific key competences have already been extensively studied.

Above, we have provided a few of our own recommendations for future research. However, the primary aim of this study was always to enable others. Researchers may use the topics in Table 1, along with the full list of articles by research stream and topic in *Supplementary material 1*, as a CBET bibliography to efficiently locate studies relevant to their areas of interest, identify under-explored topics, and design new research questions.

5. Limitations

The following limitations apply to our results. Because of technical limitations in the tool used for DCNA, our analysis was restricted to export files from a single database. This constraint is common in studies that rely on citation analysis methods (e.g. Shen and Ho, 2020). The choice of database may have induced bias in our results related to, for example, the coverage of different fields of study and the countries of publishers (Mongeon and Paul-Hus, 2016). Furthermore, a substantial number of articles were excluded from the topic analysis because our focus was on the main CBET research streams. Future research may build upon this work by using multiple databases and exploring topics outside the dominant streams.

Even though topic modelling with LSA is an established method for clustering articles based on their content, making meaningful and reliable interpretations of the patterns that the algorithms identify in an unsupervised way remains challenging. There is still a need for intelligent and cautious interpretation by the researchers prior to and after the analytic process (Kwon *et al.*, 2017). For example, processing of the data includes multiple manual steps, and the interpretation of the resulting topics is made qualitatively by the researchers. Based on our interpretation, some of the topics included few to several articles that did not seem to relate to the other articles with that topic. We excluded such outlier articles from the descriptions of the topics for conciseness but, for transparency, include the full list of articles on each topic in Supplementary material 1. We encourage readers to refer to the Supplementary Material 1 when evaluating our findings.

Supplementary material

The supplementary material for this article can be found online.

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Corresponding author
Joonas Mannonen can be contacted at: joonas.o.mannonen@jyu.fi