Journal of Computers in Education
https://doi.org/10.1007/s40692-025-00376-9

Learner emotions in collaborative learning: bibliometrics with topic modelling

Xieling Chen[1] · Di Zou[2] · Lucas Kohnke[3] · Haoran Xie[4] · Gary Cheng[5] · Fu Lee Wang[6]

Received: 14 February 2025 / Revised: 1 September 2025 / Accepted: 4 October 2025

Abstract

Learner emotions in collaborative learning have been actively researched. This paper collected 1866 papers about learner emotions in collaborative learning contexts from 2000 to 2023 and analysed them in terms of (1) research topics, (2) topics' evolutional patterns, (3) contributing countries/regions/institutions, and (4) scientific collaborations using topic modelling and bibliometrics. Our primary emphasis was on analysing article patterns, discerning the involvement of institutions, countries, or regions, illustrating partnerships via social network visualization, and uncovering significant themes and their developmental shifts via topic modelling and statistical analysis. Results indicated a steady increase in articles focusing on emotions in collaborative learning, attributed largely to the substantial input from scholars based in the USA, the UK, and Australia, alongside a rising interest among academics from Spain, China, as well as Taiwan, Province of China. Examination of regional and institutional partnerships uncovered a tendency for closely located institutions to engage in collaborative endeavours, particularly when sharing similar research focuses. The analysis of topics highlighted that learners' emotions in collaborative learning, particularly online/computer-supported collaborative learning in various settings (e.g., science, teacher, healthcare, clinical education, and language education) received increasing attention. Diverse applications (e.g., digital games, Wiki, and digital learning platforms) have flourished into collaborative learning activities to understand learners' behaviour patterns and emotional dynamics. Based on the results, a conceptual framework including seven key dimensions (i.e., contexts, emotional dimensions, collaborative methods and approaches, moderating and mediating variables, outcomes, subject domains, and theoretical foundations) was proposed to guide research on emotional experiences in collaborative learning.

Keywords Bibliometrics · Topic modelling · Social network visualization · Collaborative learning · Learner emotions

Extended author information available on the last page of the article

Published online: 16 January 2026

Introduction

Collaborative learning involves social interactions with a group of learners to acquire knowledge and share experiences (Fernandez-Perez & Martin-Rojas, 2022) and is popularly amalgamated by instructors into their instruction. Studies have reported collaborative learning's effectiveness in promoting students' learning interests, critical thinking skills and academic outcomes, and enriching knowledge construction and sharing (e.g., Haynes et al., 2023; Zou et al., 2023; Abdul Rabu et al., 2023). Nevertheless, the extent to which learners can benefit from collaborative learning's social and cognitive advantages depends heavily on group interaction effectiveness (Strauß & Rummel, 2021). To measure the interaction effectiveness and enhance learning effects, understanding learners' emotions during collaboration is essential (Järvelä et al., 2023). This is because learners involved in collaborative learning activities encounter emotional challenges caused by individual differences and dysfunctional interaction processes (Zhang et al., 2021a, 2021b). Facing strong negative emotions, individuals need to deal mentally with their emotions to retain motivation and engagement (Ferreira et al., 2019). These motivational and emotional challenges can cause frustration and move away from the group's focus from on-task activities, thus leading to ineffective collaborative learning. Emotion regulation is necessary for group members to maintain a positive learning atmosphere (Järvenoja et al., 2020) to advance interaction, communication, and engagement in collaborative knowledge construction. Hence, it is essential to understand members' affective status and emotional capacity during collaborations to monitor and control collaboration processes and improve learning gains and achievements. Consequently, learner emotions in collaborative learning are actively researched.

Scholars have investigated diverse facets of emotions in collaborative learning, for example, students' cognitive engagement in online discussions, students' awareness of socio-emotional skills, students' emotional regulation, emotional connectivity, and students' emotional awareness (e.g., Rothstein et al., 2023; Törmänen et al., 2023; Rasi & Vuojärvi, 2018). Researchers have shown interest in exploring the causes and influencing factors related to individual, contextual, and social learning that can affect learners' emotions during collaborative learning (e.g., Prestridge & Cox, 2023; Schultz et al., 2023). For instance, collaboration dynamics (e.g., different commitment and concentration levels or conflicting understanding of shared problem-solving) are found to produce negative emotions (Guo & Barmaki, 2020). Nevertheless, more in-depth studies are essential to transform these understandings into practice (Yadegaridehkordi et al., 2019). Additionally, we need more research-based evidence for supporting motivation, promoting positive emotions, and simultaneously reducing negative emotions during collaborative learning based on an overview of extant literature (Järvenoja et al., 2020). However, limited reviews have synthesised prior literature regarding learners' emotions.

Existing reviews concentrated on specific contexts (e.g., nursing or programming education), technologies (e.g., mobiles and cloud computing), analysis methodologies (e.g., social network analysis), or design and implementation characteristics of collaborative learning (e.g., teacher guidance and group formation). According to Hsu et al. (2012), this might lead to ignorance of many topics. Silva and Ferreira's

(2021) and Reis et al.'s (2018) reviews have the same research target (i.e., emotions in collaborative learning) as ours; however, similarly to other reviews, they adopted systematic analysis methodologies of a relatively small sample of articles (i.e., 5–113). Thus, their results depended heavily on a predefined coding scheme and coders' expertise. Also, they focused on specific aspects (e.g., affects and socio-emotional features). Thus, there are essential issues undiscovered, or at least not elaborated sufficiently. For example, what are the hotspots in the field? Computational methods such as rigorous bibliometrics and topic modelling appear suitable to allow large-scale articles to be analysed (Chen et al., 2024; Nguyen et al., 2023; Samsul et al., 2023; Meng et al., 2024). Results from such analyses can lead to insights into the academic foundation for new development evaluation, emerging research interests, and obstacles and paths to be tackled to facilitate intelligent computer-supported collaborative learning (CSCL).

As research on emotions in collaborative learning are becoming increasingly dynamic, it becomes important to review the extant studies to understand its current status and development and pinpoint research directions, which is crucial to advance the field's development (Duan et al., 2020). To analyse research concerning collaborative learning with emotions being considered, bibliometrics and topic models are suitable for identifying research gaps and directions in a research area (e.g., Chen et al., 2023; Mertala et al., 2024; Han, 2020).

To that end, using bibliometrics and topic modelling, this study analyses scientific literature on learner emotions in collaborative learning to recognize key research topics and depict their evolutions. We additionally summarize the characteristics of journals, regions, institutions, and international collaborations. The present work will drive the comprehension of advancements in this domain and the pertinent research and application trajectories. More specifically, the current investigation centres on three key research questions (RQs):

RQ1 What were the main research topics?
RQ2 How did the research topics develop with time?
RQ3 What were the main findings (e.g., major journals, countries/regions, institutions) of the bibliometric analysis?
RQ4 What were the collaborations among countries, regions, and institutions?

Literature review

There are reviews regarding collaborative learning (see Table A in the Appendix) that are categorised into overviews of collaborative learning, reviews focusing on specific domains or technologies, analysis methodologies, collaborative learning characteristics, and collaborative learner characteristics.

We identified an overview study on collaborative learning, which focused on educational sectors and settings, learning activities, and collaboration mechanisms. Manathunga and Hernández-Leo (2015) identified the prevalence of "co-located higher education settings using learning management systems", "open and structured discussion", and "peer assessment and collaborative writing" as learning activities, and group formation mechanisms to promote fruitful collaboration.

Several reviews focused on nursing, medicine, programming, and language education. Lerchenfeldt et al. (2019) systematically reviewed 31 studies about peer feedback's use in collaborative medical learning during 1997–2017, identifying problem- and team-based learning as prevalent settings where peer feedback was effective in professionalism development assessment. Männistö et al. (2020), Williamson et al. (2020), and Zhang and Cui (2018) focused on collaborative nursing education. Specifically, Männistö et al. reviewed five articles from 2003 to 2018, identifying digital collaborative learning's effectiveness in increasing students' knowledge and nursing skills, collaborative skills, problem-solving skills, and learning satisfaction and motivation. Williamson et al. synthesised 14 articles from 2008 to 2018 in terms of study design, data sample, data acquisition, and outcomes to comprehend collaborative strategies' influence in nursing practice, while Zhang and Cui reviewed 29 articles from 1985 to 2017 to uncover implementation methodologies, effectiveness, and influencing factors. Zhang and Cui found collaborative learning's effectiveness in the classroom and online instruction improves nursing and clinical knowledge and skills and promotes group skills and self-confidence, learning engagement, and motivation. Silva et al. (2020) and de Carvalho and de Magalhães Netto (2020) concentrated on programming education. Silva et al. reviewed 27 articles from 2015 to 2020 to understand collaborative resources, outcomes, and structure, finding the prevalence of collaborative programming editor resources and pair programming and a wide concern for learning outcomes and perception. de Carvalho and de Magalhães Netto reviewed 22 articles regarding robotics and programming education between 2014 and 2018 to understand collaborative activities, technological resources, degrees and modalities, and pedagogical concepts. de Carvalho and de Magalhães Netto identified prevalent topics, including Java and C language pair-programming activities, artificial intelligence (AI), higher education, problem-based learning, and constructivist theory. Zhang et al. (2021a, 2021b) focused on language education. By reviewing 113 articles about computer-assisted collaborative writing from 1998 to 2020 regarding study contexts and setup features, methodological design, and theories, Zhang et al. reported a common use of meaning-focused writing tasks and language learners' limited attention to form.

Several reviews focused on specific technologies and analysis methodologies. Fu and Hwang (2018) reviewed 90 articles about mobile-enhanced collaborative learning from 2007 to 2016 regarding research methodologies, devices and settings, learners, research issues, applications, grouping approaches and collaborative strategies. Fu and Hwang emphasised college students' performance while less on higher-order skills in social science education supported by collaborative learning activities. By reviewing 29 articles regarding cloud computing's use in blended collaborative learning from 2006 to 2017, Al-Samarraie and Saeed (2018) revealed their usefulness in supporting sharing, editing, communication and discussion in collaborations. Dado and Bodemer (2017) systematically reviewed 89 articles about social network analysis used in CSCL from 1999 to 2017, finding the prevalence of one-mode networks of students linked by communication-oriented relationships.

There are reviews focusing on collaborative learning characteristics. Noroozi et al. (2012) reviewed 108 articles about argumentation-based CSCL from 1995 to 2011 regarding learner characteristics and learning environments, processes, and out-

comes, highlighting the prevalence of arguing, critical thinking and reasoning. van Leeuwen and Janssen (2019) focused on understanding instructor guidance's impact on learner collaboration and learning outcomes. A systematic review of 66 relevant articles till 2018 confirmed the significance of instructors' emphasis on learners' problem-solving strategies and their support for learners' collaboration processes. By reviewing 78 articles focusing on temporal facets of CSCL from 2003 to 2019, Lämsä et al. (2021) identified major steps for CSCL temporal analysis, for example, theoretically framed research questions development, process data collection, temporal analysis methodology determination, and result interpretation based on triangulation approaches. Maqtary et al. (2019) analysed 30 articles between 2005 and 2015 to comprehend group formation attributes and techniques in CSCL.

Additionally, there are reviews focusing on learner characteristics. Mende et al. (2021) systematically synthesised 20 articles regarding individuals' preparation for collaborative learning from 1987 to 2017. According to Mende et al., individual preparation had different impacts on retrieval, inferencing, and referencing. Also, generative preparation tasks with support for students' cognitive group awareness enhanced individual preparation for collaboration. Silva and Ferreira (2021) and Reis et al. (2018) addressed learner emotions in CSCL. Silva and Ferreira reviewed 70 articles addressing emotional aspects of productive dialogues in CSCL from 1989 to 2020, finding neglect regarding emotional dimensions such as empathy in CSCL and the negative impact of negative emotions on motivations. Reis et al. reviewed 58 articles till 2018 to detect, evaluate and classify literature concerning affective states and socio-emotional factors in CSCL, discovering a wide concern of "emotional awareness" and "interaction among students" measured by questionnaires.

Data and methodologies

Figure 1 is a flowchart of data acquisition and analyses. The flowchart has three subprocesses: data collection, data screening, and data analysis, which are elaborated upon in the following subsections. Specifically, Sect. 3.1 details the procedures for dataset collection and the criteria used to screen articles related to learner emotions in the context of collaborative learning. Section 3.2 explains the data analysis methods, including topic modelling and trend analysis, which were employed to address RQs 1 and 2 concerning main research topics and their temporal development. Section 3.3 describes the analyses of performance and collaboration, conducted to answer RQs 3 and 4 that pertain to the most influential journals, countries or regions, and institutions, as well as patterns of research collaboration.

Data collection and filtering

The research articles concerning learner emotions in collaborative learning were acquired in the Web of Science (WoS) by means of a pre-defined query: "TS = ((("affect" OR "feeling" OR "mood" OR "anxiety" OR "attitude" OR "enjoyment" OR "frustration" OR "joy" OR "satisfaction" OR "engagement" OR "self-regulation") AND (CSCL OR "collaborat*" OR "cooperat*") AND (learn*))". We only

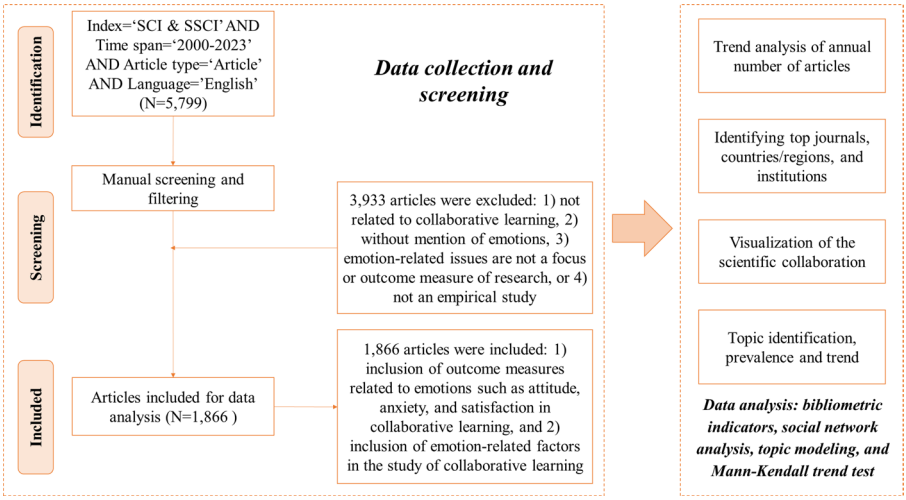

Fig. 1 Data acquisition and analysis

Table 1 Screening criteria

Criteria	I/E	Descriptions
Inclusion criteria	I1	Inclusion of outcome measures associated with emotions such as attitude, anxiety, and satisfaction in collaborative learning
	I2	Inclusion of emotion-related factors in collaborative learning
Exclusion criteria	E1	Not related to collaborative learning
	E2	Without mention of emotions
	E3	Emotion-related issues are not a focus or outcome measure of research
	E4	Not an empirical study

included publications that were: (1) research articles, (2) written in English, (3) published during 2000–2023, and (4) with Science Citation Index Expanded or Social Sciences Citation Index. Accordingly, 5799 articles were downloaded along with their bibliographic and citation information.

Two researchers conducted data filtering to guarantee its reliability following the criteria in Table 1. Specifically, they first assessed 200 articles apiece, leading to an inter-rater reliability of 96%. When inconsistencies occurred, they reached a consensus via discussion. They subsequently filtered the remaining articles. In total, 1,866 articles were labelled as relevant. Figure 2 displays the annual number of articles, which indicates a general growing tendency. Beginning with just six articles in 2000, the number gradually grew over the years, with spikes in some periods, such as from 2009 to 2013 and again from 2015 to 2022. The most significant growth occurred between 2019 and 2022, where the number of articles nearly doubled, showcasing a burgeoning interest in understanding the emotional aspects of collaborative learning. This steady rise suggests emotions' significance in educational contexts and underscores the ongoing efforts to explore their dynamics and implications within collab-

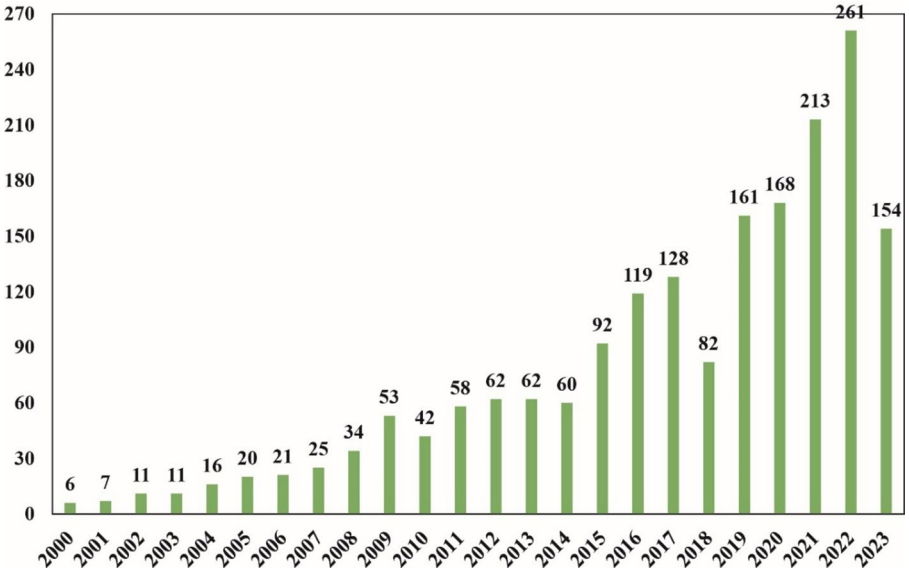

Fig. 2 Trends of articles

orative educational settings. Overall, research on emotions in collaborative learning has attracted growing attention in academia, indicating sustained interest and investment in this field of study.

Topic modelling and trend analysis

Topic modelling is utilized to discern the underlying themes within documents and to understand topics across them. This modelling technique operates on the assumption that a corpus of documents encompasses multiple topics. A topic is characterized by a frequency distribution of words across a predefined vocabulary (ϕ_k), and a word in a document (w_{dn}) is selected from the vocabularies associated with the topics. The topics adhere to the distribution θ_d. The topic model follows a generative process consisting of two steps:

Step 1. For a topic $k = 1, ..., K$.

(a) Produce a word distribution $\phi_k \sim Dirichlet(\beta)$.

Step 2. For a document $d = 1, ..., D$.

(a) Produce a topic distribution $\theta_d \sim Dirichlet(\alpha)$.
(b) For word $n = 1, ..., N$.

(i) Produce a topic $z_{dn} \sim Multinominal(\theta_d)$.
(ii) Produce a word $w_{dn} \sim Multinominal(\phi z_{dn})$.

The mechanism of structural topic modelling (STM) mirrors that of Latent Dirichlet Allocation (LDA) (Roberts et al., 2014). However, STM (Fig. 3) diverges from LDA in that it incorporates prior structural details derived from generalized linear models with document-specific covariates, denoted as X and U, serving as parameters. Our implementation of STM was performed utilizing the R package *stm* (Roberts et al., 2019).

In this study, the primary materials for topic modelling were titles and abstracts. The procedure of topic modelling and trend analysis included the following steps. First, terms were extracted from titles and abstracts. Second, pre-processing was executed, including stop word removal, similar term consolidation, and term conversion into singular form and lowercase. Third, term frequency-inverse document frequencies (TF-IDF) filtered out less important terms based on a TF-IDF value ≥ 0.05. Fourth, topic modelling was performed to run 26 models with the range of topics varying from five to thirty, computing each model's semantic coherence and exclusivity. According to Fig. 4, the model including 15 topics with better scores for both semantic coherence and exclusivity outperformed others and was thus used for identifying topics covered within the 1,866 articles.

We then performed the following analyses, including topic interpretations, proportions, annual distributions, and topical distributions of top countries/regions/institutions. Firstly, two researchers translated the statistical results into labels for the 15 topics based on three stages: interpreting representative terms' semantic meanings, examining representative studies, and comparing labels to reach an agreement (Chen et al., 2020).

Take the topic of *technology acceptance* as an example. Two researchers observed that most of the representative terms, for example, "ease", "technology", "intention", "usage", "usefulness", and "acceptance" were associated with technology acceptance. They went on to examine the three most representative studies. Padilla-Meléndez et al. (2008) employed a modified technology acceptance model (TAM) through structural equation modelling to elucidate perceived self-efficacy's impact on the inclination to utilize Internet-powered online collaboration tools. Sarwar et al. (2019) investigated the perception and adoption of social media in collaborative learning and learner performance, integrating TAM and constructivism theory. Al-Rahmi et

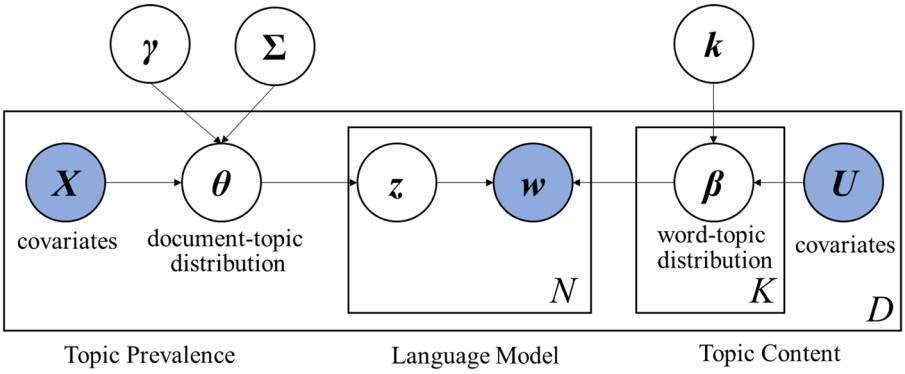

Fig. 3 A graphic model of STM

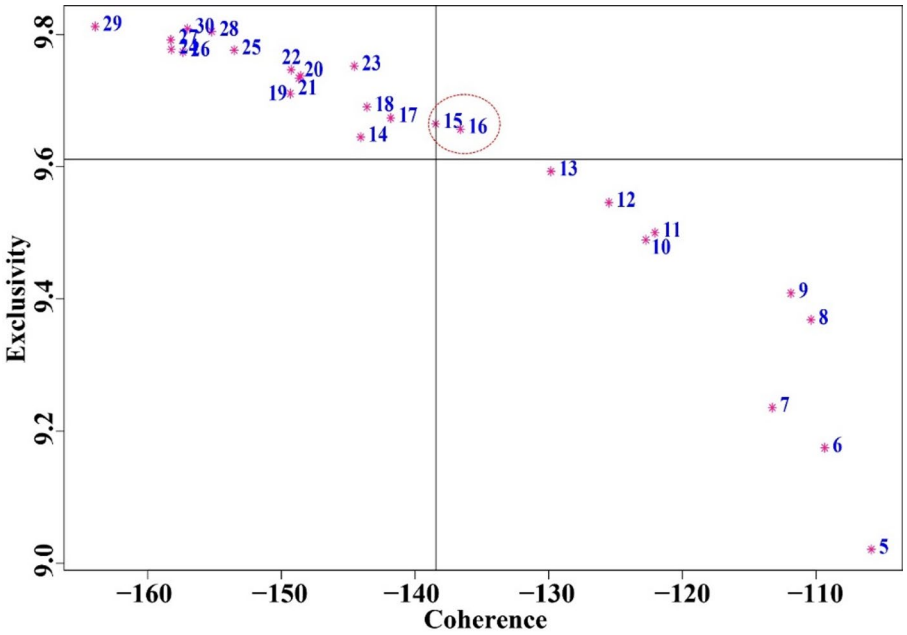

Fig. 4 Model diagnostics

al. (2020) devised a questionnaire with the guidance of both TAM and constructivism theory. In alignment with the examination results, the two researchers labelled the topic as technology acceptance. Labels for other topics were determined based on the same examination procedure.

We then calculated topics' proportions based on θ matrix, in which θ_{ij} ($i = 1,2,...,1866, j = 1,2,...15$) indicates the likelihood of paper i being linked to topic j. We investigated each topic's tendencies based on the Mann-Kendall statistical test (Mann, 1945). In this study, p-value correction methods (e.g., Holm's correction) were not applied, as the analysis of topic trends using the Mann-Kendall test was exploratory in nature. The primary objective was to identify general developmental patterns among the topics generated through topic modelling, rather than to test predetermined hypotheses.

Performance and collaboration analysis

Performance analysis included analysis of articles and the identification of top journals/countries/regions/institutions. First, article count was used to assess the influence of the publications. In addition, the scientific collaboration analysis was conducted using social network analysis by using Gephi (Bastian et al., 2009) to picture the collaborations between institutions/countries/regions.

Results

The results of the data analysis are illustrated in this section. Specifically, Subsection 4.1 outlines the major research topics identified through topic modelling, highlighting the predominant research issues in the field of learner emotions in collaborative learning. Subsection 4.2 presents the results of the trend analysis, demonstrating how key research topics have evolved over time. Subsection 4.3 reports the findings of the performance analysis, focusing on leading journals, countries/regions, and institutions. Subsection 4.4 summarizes the main findings related to collaboration patterns in the field, including institutional partnerships and regional cooperation.

Key research topics

Topic modelling analysis shows the four most-discussed topics: Digital learning platforms (9.44%), Professional development of teachers (9.37%), Game-based learning (7.72%), and Interdisciplinary clinical practices (7.30%) (see Fig. 5). Seven topics have a proportion of above 6%, including Interactive science learning in diverse settings (6.90%), Creative interactions in education and society (6.80%), Multifaceted

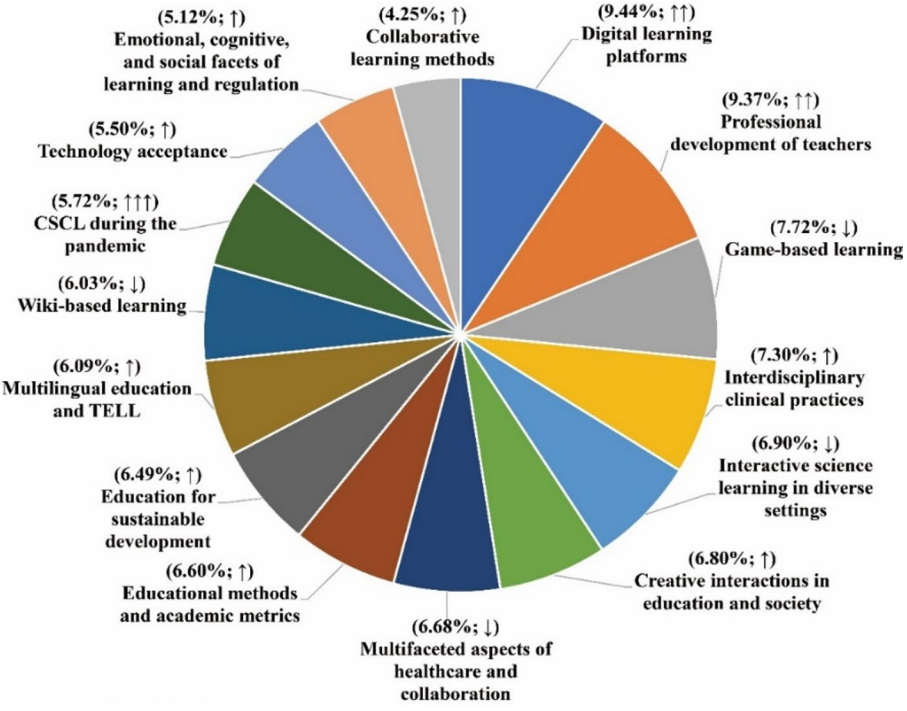

Fig. 5 Topics with proportions (Note. Arrows indicate the direction and statistical significance of the trend for each topic based on the Mann-Kendall test. ↑ or ↓ represent an increasing or decreasing trend that is not statistically significant ($p>0.05$); ↑↑ or ↓↓ indicate a statistically significant increasing or decreasing trend at the $p<0.05$ level; ↑↑↑ or ↓↓↓ denote significance at the $p<0.01$ level; and ↑↑↑↑ or ↓↓↓↓ represent a highly significant trend at the $p<0.001$ level)

aspects of healthcare and collaboration (6.68%), Educational methods and academic metrics (6.60%), Education for sustainable development (6.49%), Multilingual education and TELL (technology-enhanced language learning) (6.09%), and Wiki-based learning (6.03%). In addition, there are four topics that have received less attention compared to the above topics. These four topics are CSCL during the pandemic (5.72%), Technology acceptance (5.50%), Emotional, cognitive, and social facets of learning and regulation (5.12%), and Collaborative learning methods (4.25%). These 14 topics show depict the general and broad interests of researchers focusing on learner emotions in collaborative learning from 2000 to 2023.

Topic evolution

The trend test indicates three topics, Digital learning platforms, Professional development of teachers, and CSCL during the pandemic, experiencing a significant increasing tendency. Figure 6 shows how these topics are distributed across the study period—for example, Wiki-based learning was primarily researched from 2003 to 2009. Game-based learning and Interactive science learning in diverse settings were

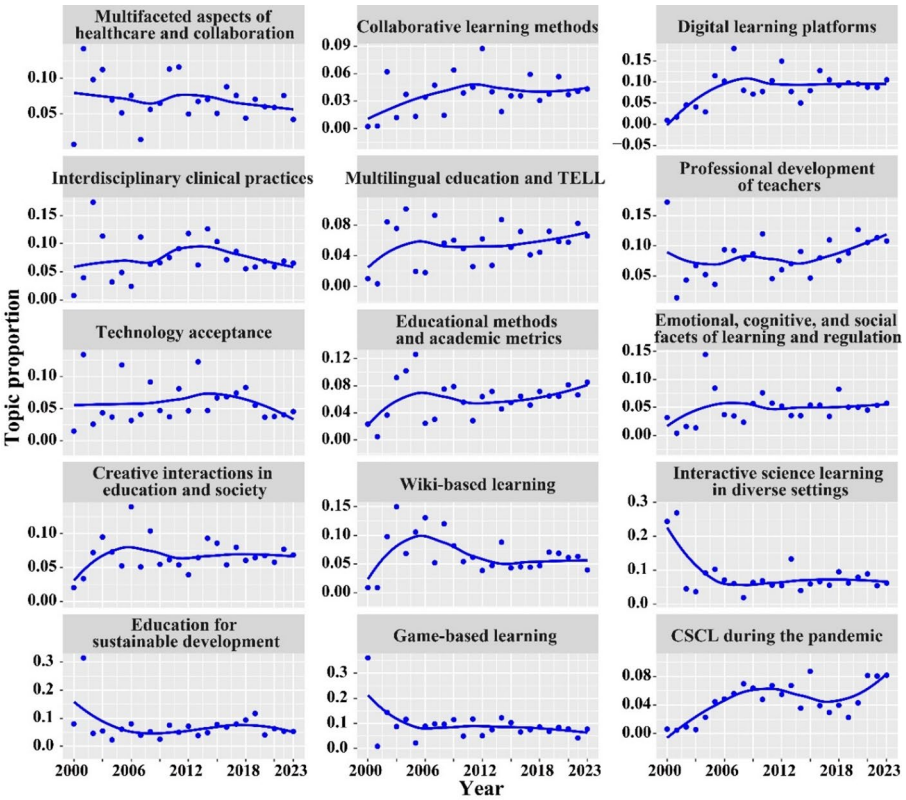

Fig. 6 Yearly distribution of topics and developmental patterns

primarily researched from 2000 to 2005. CSCL during the pandemic has become a research hotspot since 2008.

Main findings concerning performance analysis

The publication of 1866 articles across 475 journals (see Fig. 7) highlights the interdisciplinary nature of research on learner emotions in collaborative learning, with a significant emphasis on periodicals bridging computer science and education. Journals like Computers & Education, Education and Information Technologies, British Journal of Educational Technology, Interactive Learning Environment, and Australasian Journal of Educational Technology highlight the significance of leveraging novel technologies from computer science to understand and facilitate collaborative learning experiences. Additionally, the presence of articles in subject-specific journals such as BMC Medical Education, Journal of Chemical Education, Nurse Education Today, and International Journal of Engineering Education demonstrates the broad applicability and relevance of studying emotions in collaborative learning across diverse domains, indicating a rich landscape for interdisciplinary research and application.

Research on learner emotions in collaborative learning is conducted worldwide. When looking through a country/region-based lens (see Fig. 8), the growth in articles is attributable to the considerable contributions of researchers from the USA (with 605 articles), UK (with 195 articles), and Australia (with 154 articles), as well as the increased interest among scholars affiliated with non-English-speaking regional institutions (e.g., Spain, China, the Netherlands). In terms of institutions (see Fig. 9), the University of Washington emerges as the leading contributor with 25 articles, followed closely by the University of Hong Kong, Indiana University Bloomington, and Beijing Normal University, each with 23 articles. These findings highlight the global interest and engagement in studying the emotional dynamics of collaborative learning. Additionally, institutions such as the University of Oulu, National Taiwan Normal University, Michigan State University, and the Education University of Hong Kong also make substantial contributions to the field, underscoring the varied

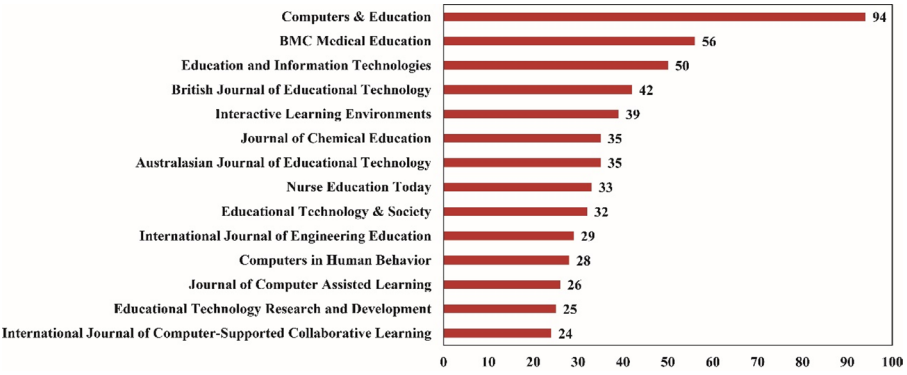

Fig. 7 Top journals

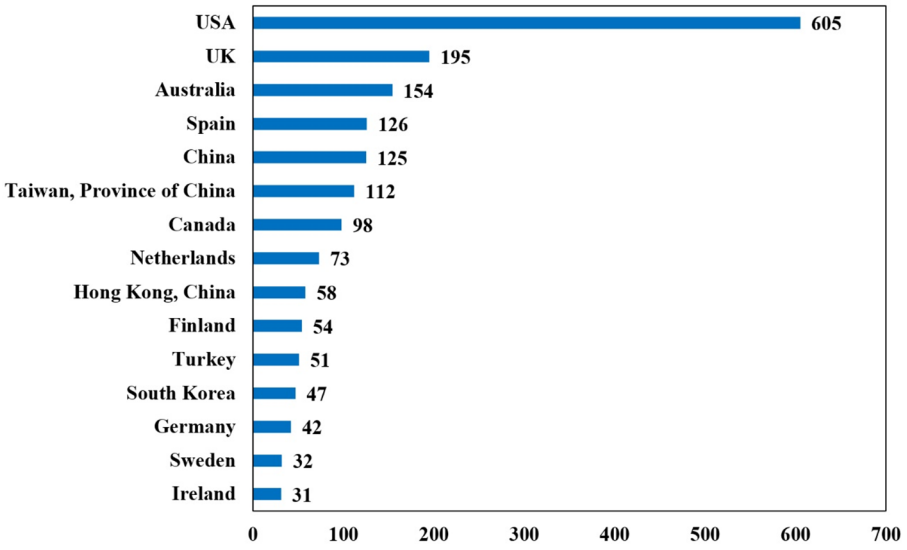

Fig. 8 Top countries or regions

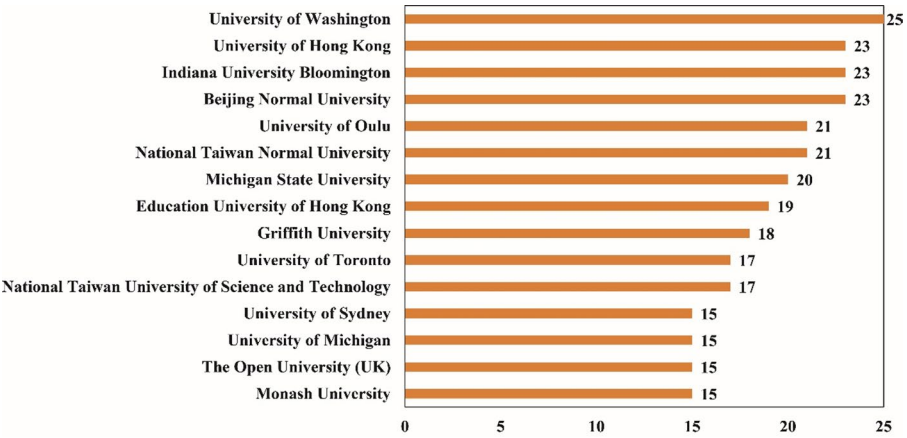

Fig. 9 Top institutions

academic institutions engaged in promoting the understanding of the intersection between emotions and collaborative learning processes.

Main findings concerning collaboration analysis

In our analysis, scientific collaboration between countries or institutions was defined based on co-authorship involving affiliations from different countries or institutions, following the definition proposed by Sonnenwald (2007). Specifically, if a publication included authors affiliated with multiple countries or institutions, each unique

pair of affiliations was considered a single instance of collaboration. For example, consider an article with five authors (A1, A2, A3, A4, A5) affiliated with countries C1, C2, C2, C3, and C4, respectively. This article would be treated as evidence of collaborative links between each unique country pair: C1–C2, C1–C3, C1–C4, C2–C3, C2–C4, and C3–C4. Thus, it would contribute six instances (or "collaborative links") to the country-level collaboration network. The same principle was applied at the institutional level.

This approach enabled us to quantify the frequency of co-occurrence of countries or institutions in multi-authored publications, which we refer to as collaborative frequency. More precisely, in this study, collaborative frequency denotes the number of times two distinct countries (or institutions) appear together as affiliations in co-authored scholarly articles. Each unique co-affiliation pair in a publication is counted as one collaboration instance, and the total number of such instances across all articles represents the collaboration frequency between the two entities.

Table 2 summarizes the collaborative partners and their corresponding collaborative frequencies for both country-level and institutional-level collaborations, considering only those with a minimum frequency of 5 and 3, respectively.

Figure 10 illustrates the partnerships between nations/regions, with collaborative occurrences between 5 and 24. Four partners have collaborated in the number of articles ranging from 13 to 24, including (1) the USA and Canada, (2) the USA and China, (3) the USA and the UK, and (4) the USA and Australia. Looking at the collaborations with frequency ranging from 11 to 12, there are 4 partners, including (1) the USA and South Korea, (2) China and Taiwan, Province of China, (3) China and Hong Kong, China, as well as (4) Australia and the UK. There are 4 partners having a collaborative frequency ranging from 6 to 8, including (1) Canada and Australia, (2) the USA and Israel, (3) the USA and Hong Kong, China, as well as (4) Ireland and the UK. Looking at the collaborations with frequency OF 5, there are 5 partners, including (1) Australia and Finland, (2) Netherlands and the UK, (3) the UK and South Africa, (4) Macao and China, as well as (5) the USA and Thailand.

Figure 11 shows collaborations among institutions, demonstrating collaborative occurrences ranging from 3 to 4. Four partners have collaborated on 4 articles, including (1) National Central University and Yuan Ze University, (2) Open University of the Netherlands and University of Utrecht, (3) Beijing Normal University and Beijing University of Posts and Telecommunications, and (4) Mississippi State University and University of Macau. Additionally, institutions' collaborations within the same countries or regions appear to be tight, evident from numerous collaborative alliances such as (1) University of Melbourne and Monash University, (2) University of Western Australia and Edith Cowan University, (3) Michigan State University and University of Michigan, (4) Harvard Medical School and Brigham and Women's Hospital.

Table 2 Regional and institutional collaborations with a minimal collaborative frequency of 5 and 3, respectively

Types	Collaborative partners	Collaborative frequency
Regional collaborative partners	Canada–USA	24
	China–USA	19
	UK–USA	13
	Australia–USA	13
	Australia–UK	11
	Taiwan, Province of China–China	11
	Hong Kong–China	11
	South Korea–USA	12
	Israel–USA	8
	Taiwan, Province of China–USA	8
	Ireland–UK	6
	Canada–Australia	6
	South Africa–UK	5
	Thailand–USA	5
	Macao–China	5
	Netherlands–UK	5
	Finland–Australia	5
Institutional collaborative partners	Yuan Ze University–National Central University	4
	Beijing University of Posts and Telecommunications–Beijing Normal University	4
	Mississippi State University–University of Macau	4
	University of Utrecht–Open University of the Netherlands	4
	University of North Carolina at Charlotte–Old Dominion University	3
	Brigham and Women's Hospital–Harvard Medical School	3
	Wenzhou University–National Taiwan University of Science and Technology	3
	Peking University–Beijing Normal University	3
	King Mongkut's University of Technology Thonburi–Pennsylvania State University	3
	Simon Fraser University–University of Victoria	3
	University of Groningen–Maastricht University	3
	University of Groningen–Leiden University	3
	University of Western Australia–Edith Cowan University	3
	Rutgers University–Indiana University Bloomington	3
	University of Melbourne–Monash University	3
	Chinese University of Hong Kong–University of Hong Kong	3
	University of Michigan–Michigan State University	3
	National Taiwan University of Science and Technology–National Taiwan Normal University	3
	Education University of Hong Kong–University of Hong Kong	3

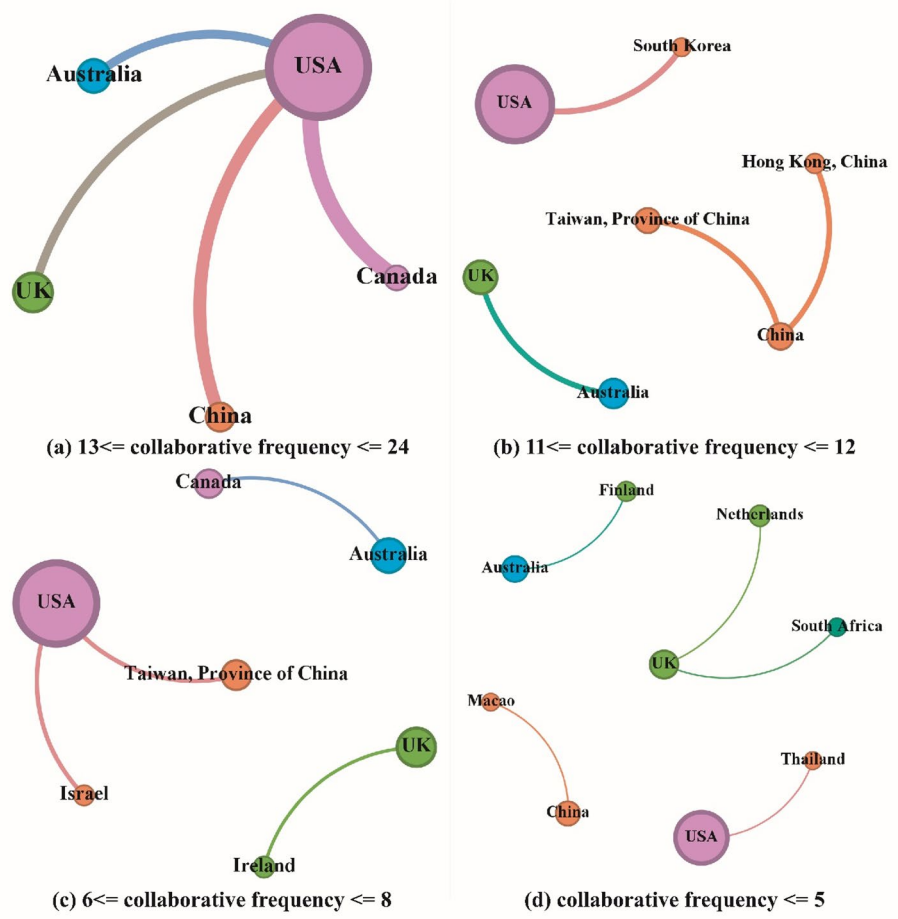

Fig. 10 Collaborations among countries/regions

Discussion

The present work provided an overview of research on emotions in collaborative learning contexts by employing topic modelling and bibliometric analysis. The focus was on examining research topics and their evolution, identifying leading journals, countries/regions, and institutions, as well as exploring patterns of academic collaboration. This section discusses the results derived from the data analyses. Specifically, Sect. 5.1 summarizes the key findings in relation to the four RQs posed. Section 5.2 compares the findings of the current work with those of prior literature reviews, highlighting similarities and differences, and demonstrating how this study offers new insights or updates to the extant body of knowledge. The practical implications of the findings for teaching and learning are presented in Sect. 5.3, along with proposed avenues for future research based on identified gaps and emerging trends. Section 5.4 introduces a conceptual framework developed from the research findings, aimed at

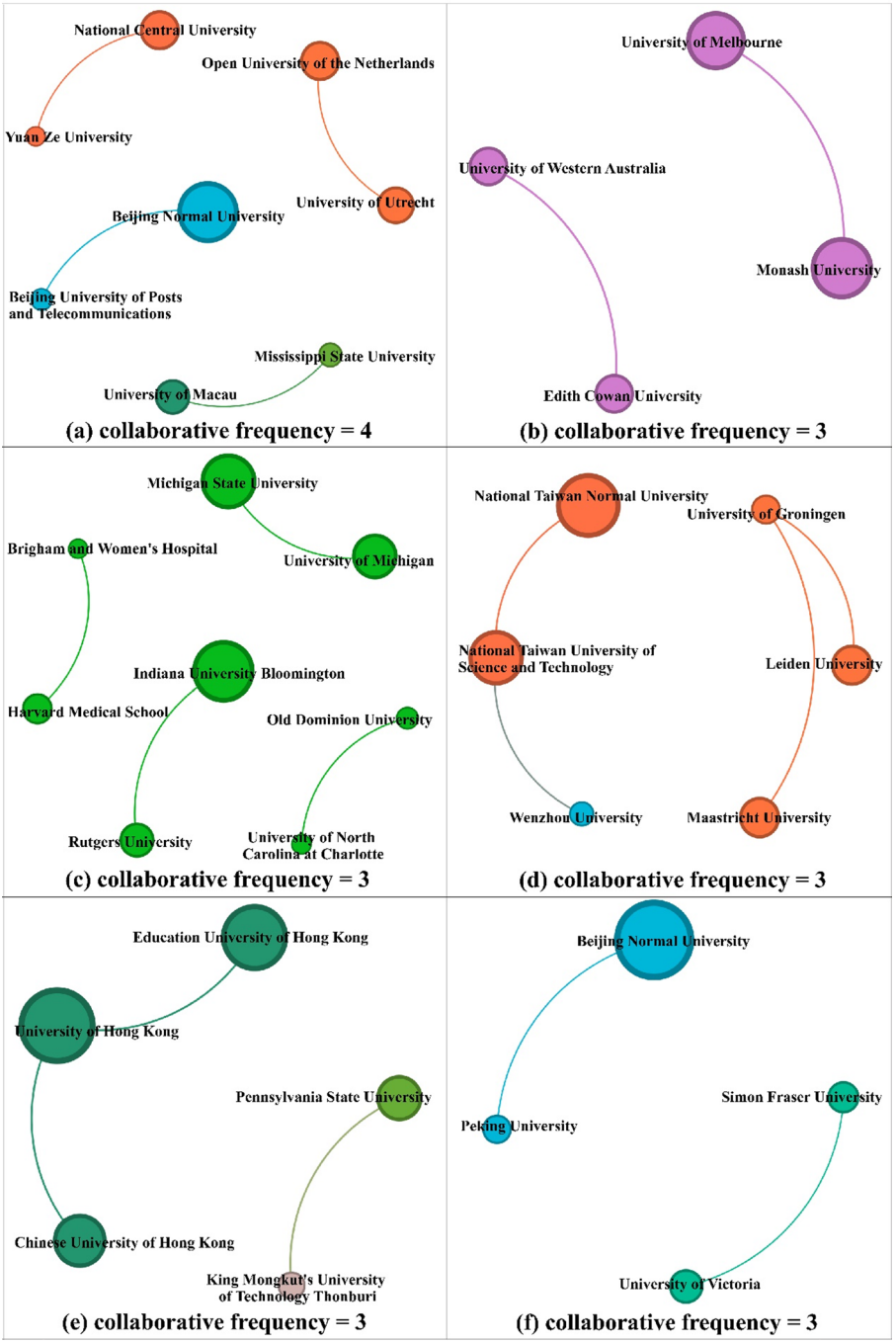

Fig. 11 Collaborations among institutions

guiding future studies. Finally, Sect. 5.5 acknowledges the limitations of the current review and suggests directions for future work to build upon its findings and address its constraints.

In response to RQs

The present bibliometric study, enhanced by topic modelling, explores contributors, collaborations, and research themes related to learner emotions in collaborative learning contexts. From Fig. 2, there are three waves of research: before 2008, during 2009–2014 and from 2015 onwards, driven by a growing interest in understanding emotions in educational contexts and increased efforts to explore their dynamics and implications within collaborative educational settings.

The findings from STM address RQ1 by uncovering common issues that surfaced consistently during the review period, for example, collaborative learning instruction integrated with varied technologies and applications, especially wikis, digital games, and digital learning platforms. All these aid in achieving various educational objectives, including gaining subject expertise and competencies related to, for example, language and multilingual, teaching, healthcare, science, and interdisciplinary clinical, particularly through the implementation of creative teaching methods (e.g., CSCL, game-based learning and interactive learning). The top popular issues related to learner emotions are found in digital collaborative learning platforms and game-based collaborative learning contexts, as well as during collaborative practices for the professional development of teachers. We also revealed a wide concern for learner emotions during CSCL in different domains (e.g., teacher, multilingual, language, sustainable, science, healthcare education, and interdisciplinary clinical practices). We additionally identified attention for learners' emotional, cognitive, and social facets of regulated learning and in CSCL during the pandemic.

The results of the topic analyses, particularly the trend examination, address RQ2 by demonstrating a heightened level of interest in digital education platforms, teacher professional training, and CSCL during the pandemic between 2000 and 2023. On the contrary, issues related to game-based learning, science learning, healthcare education, and wiki-based learning have gradually become less popular in the studied period. Comparatively, researchers have devoted efforts to developing collaborative learning methods and academic metrics to promote and measure learners' emotion, cognition, social, and creative skills as well as perceived technology acceptance in diverse CSCL contexts such as interdisciplinary clinical practices, sustainable development education, multilingual education and TELL in recent years.

In response to RQ3, current research on learner emotions in collaborative learning is scattered across various sources. However, as depicted in Fig. 7, out of 548 papers published across the top 14 sources, approximately 45% were found in just four journals: Computers & Education, BMC Medical Education, Education and Information Technologies, and British Journal of Educational Technology. The remaining journals had fewer than 40 papers each. Therefore, we advocate for the initiation of special issues dedicated to learner emotions in collaborative learning contexts to stimulate increased academic productivity in this area.

In the country and region analyses (Fig. 8), the noteworthy growth of the number of studies is due to substantial contributions from the USA, UK, Australia, Spain, and various Asian countries/regions, for instance, China and South Korea. Affiliation analysis further indicates substantial contributions from institutions in the USA and Asia. Affiliations, e.g., University of Washington and University of Hong Kong, play pivotal roles in studying learner emotions in collaborative learning contexts, as illustrated in Fig. 9.

In addressing RQ4, as indicated by Fig. 10, countries/regions exhibiting heightened international collaborations experienced notable growth, exemplified by the USA, the UK, Australia, and China, all of which rank prominently in terms of productivity according to Fig. 8. This underscores the significance of international collaborations within the research realm of learner-related emotions in collaborative learning contexts. Figures 10 and 11 also indicate that countries, regions, or affiliations within the same geographic areas demonstrate a greater propensity for research collaboration. This is because of the ease and convenience of communication. Nevertheless, there is a need to increase cross-regional collaborations to effectively address challenges as the field of learner-related emotions in collaborative learning progresses (Guerrero Bote et al., 2013).

Compared to previous reviews

The present work investigated the thematic structure of research concerning emotions in collaborative learning through bibliometrics and STM. Based on 1866 research articles, we uncovered major research concerns and their developmental tendencies. Besides identifying the prevalence of collaborative learning in higher education (Manathunga & Hernández-Leo, 2015; de Carvalho & de Magalhães Netto, 2020; Fu & Hwang, 2018), we also highlighted concern about emotions during collaborative learning in teacher training. Such a result contradicts Fu and Hwang's (2018) findings of little research on teachers and adults. In addition to identifying nursing, clinical, science, and language education (Zhang et al., 2021a, 2021b; Männistö et al., 2020; Zhang & Cui, 2018; Fu & Hwang, 2018), we further identified interprofessional education. Besides the prevalence of problem-based collaborative learning and its effectiveness in promoting problem-solving skills highlighted in several reviews (Lerchenfeldt et al., 2019; de Carvalho & de Magalhães Netto, 2020; Männistö et al., 2020; van Leeuwen & Janssen, 2019), we demonstrated collaborative learning's effectiveness for developing creative thinking abilities. We also identified a wide range of applications, for example, wikis, digital learning platforms, and digital games. Similar to Lerchenfeldt et al. (2019)d nnistö et al. (2020), our study identified collaborative learning's prevalence for promoting students' knowledge and skills such as clinical competency, collaborative skills, and professional development.

Pedagogical implications and future directions

Drawing upon the findings of this comprehensive bibliometric and topic modelling analysis, we provide pedagogical implications and suggest future directions in the domain of learner emotions in collaborative learning contexts.

Firstly, educators and policymakers can utilize the identified major research topics, such as digital learning platforms and professional development of teachers, to inform curriculum design and pedagogical practices, thereby fostering more emotionally supportive and effective collaborative learning environments. For example, language instructors could adopt wikis to engage learners in collaborative writing activities. A special focus could be the provision of procedural and collective scaffoldings, such as self-evaluation approaches like self-assessment questionnaires and focus-group interviews, to promote learners' self-regulation and support for goal settings to promote and sustain learner engagement. Another application that instructors can exploit is collaborative games, which, by providing reciprocal interaction, can improve learner enthusiasm, enjoyment and curiosity, involvement in learning. However, instructors should integrate competition into collaborative educational games to effectively enhance learners' motivation and performance by considering collaborative games' problems like free-rider issues, responsibility diffusion, and negative groupthink effects. Future research should delve deeper into emerging topics like collaborative learning methods and academic metrics, ensuring a holistic understanding of the emotional dynamics within collaborative settings.

Effective as the technologies mentioned above produce positive emotions such as engagement and enjoyment to support collaborative learning, instructors need to provide timely and adaptive support to promote socially shared regulation (Tang et al., 2023; Yildiz Durak & Atman Uslu, 2023). To achieve this, instructors can apply multimodal and process-oriented approaches based on motivational and emotional process data simultaneously collected by physiological devices to constantly understand learner motivation and emotion regulation (Zhang & Yu, 2024; Järvelä et al., 2023). However, interdisciplinary efforts are required to fully exploit the collected multimodal data's potential for supporting learners' emotion regulation and motivation during collaboration. Thus, it is suggested that international collaborations are significant for cross-cultural perspectives in advancing the field. Educators and researchers alike are encouraged to foster partnerships across regions to enrich the diversity of insights and approaches, ultimately enhancing the global impact of research on learner emotions in collaborative learning. This means that instructors need to collaborate with data scientists to derive important insight into smart and meaningful collaborations and interactions from the unobtrusive multimodal data channels by using advanced analytical technologies.

The evolving trends highlighted in this study underscore the importance of staying abreast of technological advancements and adapting instructional strategies to satisfy learners' changing requirements (ElSayary, 2024). Drawing upon the latest AI trends and technologies, future studies on learner emotions in collaborative learning contexts can be further enhanced by considering the following aspects. Firstly, leveraging AI-powered sentiment analysis and emotion recognition systems can provide real-time feedback to educators (Ahmad et al., 2023), enabling them to tailor interventions and instructional strategies based on students' emotional states during collaborative learning activities. This personalized method can foster more supportive learning environments and promote emotional well-being and engagement among students. Examples include neural network-based affective computing for emotion detection and prediction, advanced SEM coupled with visualisation technologies to

analyse and visualise emotions' relationships with learner outcomes and collaborative learning conditions, and collaborative filtering to offer personalised and real-time feedback according to both personal and group characteristics. The adaptive feedback about students' actual functioning in the group and their personality characteristics, such as attachment orientations, are helpful for instructors to effectively provide guidance to deal with students' group-related difficulties. To effectively deal with group-related difficulties, instructors should carefully design effective approaches for group formation, an example of which is the use of genetic algorithms to consider the heterogeneity of individuals' knowledge levels and the homogeneity of group interactions.

Additionally, progress in natural language processing and machine learning can facilitate more nuanced analyses of textual data from collaborative learning platforms (Tan et al., 2022; Jim et al., 2024), uncovering subtle emotional nuances and patterns that may elude traditional methods. Future research directions could explore the integration of AI-driven chatbots or virtual agents into collaborative learning environments, providing on-demand emotional support and guidance to learners when they engage in complicated learning tasks.

Moreover, considering the growing importance of interdisciplinary collaboration, future studies could leverage AI-driven recommendation systems to facilitate knowledge exchange and collaboration among researchers from diverse domains (Musick et al., 2023), accelerating the development of innovative pedagogical approaches and interventions informed by insights from cognitive science, affective computing, and educational psychology. Embracing these cutting-edge AI technologies and interdisciplinary collaborations holds immense promise for advancing our understanding of learner emotions and enriching the pedagogical practices in collaborative learning contexts, ultimately empowering educators to cultivate emotionally supportive and inclusive learning environments to support learners' holistic development and academic success.

Conceptual framework for research on emotions in collaborative learning

By examining and interpreting the top representative studies of each research topic identified from the topic modelling results, this study developed a conceptual framework (see Fig. 12) including seven key dimensions (i.e., contexts, emotional dimensions, collaborative methods and approaches, moderating and mediating variables, outcomes, subject domains, and theoretical foundations) to be considered in research on emotional experiences in collaboration.

First, the contexts in which collaborative learning occurs shape learners' emotional experiences in the increasingly prevalent include digital learning platforms, hybrid models, and interdisciplinary approaches identified in the topic modelling, especially during the pandemic where the transition to remote and online education brought forth unique emotional challenges (e.g., feelings of isolation, disengagement, and frustration) (Bergdahl, 2022). Research can thus investigate how emotions such as stress, anxiety, and motivation are influenced by digital and hybrid learning settings and how they impact learner engagement and emotional responses compared to traditional classrooms. In addition, as interdisciplinary approaches to collaboration

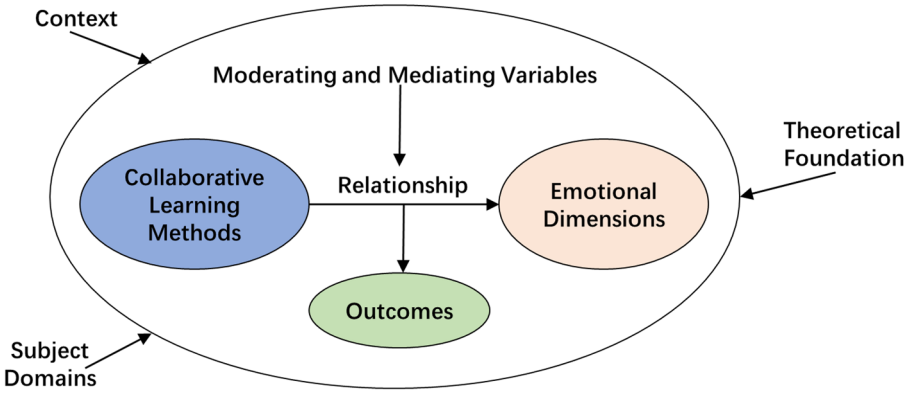

Fig. 12 Conceptual framework for research on emotions in collaborative learning

could trigger social emotions (e.g., trust, respect, or frustration) due to group members from diverse academic backgrounds (Maloney et al., 2022), researchers could explore how diverse groupings affect emotions and group collaboration performance.

Second, learner emotions, as a central role in collaborative learning, influence not only motivation but also the social and relational dynamics within a group (S. E. Tan & Jung, 2024). Motivational emotions such as excitement and joy are often observed when students are enthusiastic about their tasks, particularly in game-based learning or interactive science learning identified in the results to enhance collaboration and lead to improved academic outcomes. Nevertheless, negative emotions like anxiety and stress often emerge when learners feel overwhelmed by the complexity of tasks or when technological issues arise in digital platforms (Marsh et al., 2022). Thus, attention should be paid to how emotion regulation strategies (e.g., mindfulness, support systems, or cognitive reframing) can be employed to manage negative emotions and enhance collaborative outcomes.

Third, the methods and structures of collaborative learning such as wiki-based learning or peer learning identified in this study can promote both social (e.g., trust and empathy) and negative (e.g., conflict or misunderstanding) emotions. Emotions related to group composition, such as cultural differences or diverse skill levels, also have a profound effect on how learners collaborate and how emotionally engaged they feel (Mänty et al., 2020). It is thus essential to explore how group composition (e.g., gender, cultural background, or prior knowledge) affects learners' emotional experiences. Additionally, the role of tools and technologies in facilitating or hindering group collaboration is another area to be investigated for their impact on social cohesion and emotional regulation in a group.

Fourth, the emotional dynamics of collaborative learning are also shaped by various moderating and mediating variables. For instance, a learner's cognitive style (e.g., independent or collaborative) could influence their emotional experience in group learning (Taheri et al., 2019); similarly, the level of technological familiarity can either ease or exacerbate the emotional challenges faced by learners in digital platforms (Manca & Delfino, 2021). Therefore, researchers could explore the ways in which moderating variables such as individual cognitive differences or prior expe-

riences with technology affect emotional outcomes in collaborative learning. For example, a student who is comfortable with technology might experience confidence and engagement, whereas a less familiar learner may experience anxiety or frustration. Additionally, social support from peers and instructors can act as a mediating factor that buffers negative emotional experiences and fosters more supportive learning environments (Ruzek et al., 2016). Thus, researchers should investigate how to design collaborative learning environments that support emotional well-being, especially for learners with different levels of tech familiarity or collaborative preferences.

Fifth, the outcomes of both academic and emotional are influenced by how learners manage and navigate their emotions throughout the collaborative learning process. Academic performance is often tied to emotional engagement in game-assisted learning and interactive science education (Cheng et al., 2020), as highlighted in this study. Researchers can explore how positive emotions like motivation and joy foster better engagement and learning success in collaborative settings. For negative emotions such as anxiety or frustration that can hinder collaboration and performance (Tan & Jung, 2024), an area for further investigation could be how emotional outcomes (e.g., sense of achievement, social inclusion, and emotional resilience) are influenced by different learning contexts (e.g., multilingual education or sustainability education). Additionally, research on the continuing influence of collaborative learning on emotional resilience and career readiness could provide insights into how collaboration shapes learners beyond the classroom.

Furthermore, the subject domains (e.g., science learning, healthcare collaboration, sustainable education, and language learning) highlighted in the results contribute to shaping how emotions are experienced in collaboration. For example, interactive science learning is an area where students work together on science-based projects to experience curiosity, joy, and engagement (Törmänen et al., 2023); thus, researchers could explore how positive emotions in science learning contribute to deeper learning and problem-solving in teams. In healthcare education where the emotional dynamics (e.g., empathy and trust) are important for collaboration (Hagqvist et al., 2020), it is crucial to investigate how emotion regulation influences collaboration and learning outcomes. In education for sustainable development (Dür & Keller, 2019), researchers could examine how emotional engagement in sustainability projects leads to better group dynamics and long-term social impact. In addition, in multilingual education where emotional challenges like language anxiety and confidence are prevalent in collaborative learning (Schultz et al., 2023), researchers could investigate how emotion regulation affects collaboration and overall language proficiency.

In addition, theoretical foundations such as emotion regulation theory (e.g., Mänty et al., 2023; Zhang et al., 2021a, b; Zhang & Gao, 2024), social and emotional learning (SEL) (e.g., McMain, 2024; Appel et al., 2023; Hatton-Bowers et al., 2023), and collaborative learning theory (e.g., Rashid et al., 2023; Ouyang & Dai, 2022) can be integrated to guide and frame research on learner emotions in collaborative learning for supporting emotional regulation and understanding how emotions impact collaboration processes and outcomes. For example, emotion regulation theory provides a lens through which to explore how learners regulate their emotions when faced with challenges in conflicts or unfamiliar collaboration tasks. As a robust framework for understanding and improving emotional awareness and regulation in group settings,

researchers can investigate how SEL programs or practices can be integrated into collaborative learning to develop emotional competencies like empathy, self-awareness, and social skills. In addition, collaborative learning theories help understand how the social dynamics within groups influence emotional experiences and learning outcomes. By integrating these theories, researchers can better understand how emotions impact the learning process and how to create environments that support emotional development.

In sum, the proposed conceptual framework offers a structured way to investigate learner emotions in collaborative learning by connecting seven key components with the important topics identified in the topic modelling results. By investigating these areas, scholars are able to obtain deeper insights into how emotional experiences shape collaboration and also help them design emotionally supportive learning environments that promote positive emotional outcomes and successful collaboration.

Limitations and future work

This work has constraints. Initially, the examination relied on the WoS database. Although the WoS is widely adopted for literature assessments, certain articles pertaining to emotions in collaborative learning might not be included. Subsequent investigations could explore the potential variations in research topics within the field by encompassing articles from additional journal outlets and possibly relevant conference proceedings.

The STM-driven bibliometric approach adopted in the present study is different from systematic analysis methodologies that concentrate on pre-determined aspects of a small sample of studies. The STM approach focuses on analysing relevant studies in large volumes based on machine learning and modelling instead of pre-determined codes. Therefore, the topics identified are not predictable or constrained to emotions/collaborations. Providing that the topics have been popularly studied by scholars, they will be identified. These topics involve applications for supporting collaborative learning, for example, social networks and computer games, and learning settings where collaborative learning takes place, for example, special education and nursing education. The STM-driven bibliometrics, as a big data analytical approach, is effective in "understanding the historical and extant research progress, the development of technologies applied, and the drivers of fresh ideas (p. 29)" (Chen et al., 2022). Nevertheless, while the topic model is recognized for its capacity to unveil topical patterns, subsequent research could explore integrating text analytics techniques with qualitative analytical approaches to attain a more nuanced comprehension. This necessitates the development of methodologies enabling the automated systematic analysis of large datasets.

Conclusion

Our study presents a topic-based bibliometric analysis of research output about learner emotions in collaborative learning, focusing on research topics and their evolutions. Emotions are increasingly considered by authors devoted to collaborative

learning research, particularly online collaborative learning and CSCL. Results from topic modelling depicted top topics among scholars, including Digital learning platforms, Professional development of teachers, Game-based learning, and Interdisciplinary clinical practices. The increasingly mentioned topics revealed an increasing concern for digital learning, teachers' professional development, and CSCL during the pandemic. Other important issues in this field were also identified. Numerous applications, especially digital games and wikis, are prevalent in supporting collaborative learning. Regarding learning contexts, increasing attention has been attached to collaborative strategies in science education, teacher education, healthcare and clinical education, and language and multilingual education, especially through CSCL and collaborative interdisciplinary learning activities. Another notable tendency is the attention to emotional, cognitive, and social facets of learning and regulation in CSCL contexts. The present work contributes to promoting the understanding of the present state and prospective trajectories of research concerning learner emotions in collaborative learning. Additionally, it provides crucial insights for stakeholders such as field decision-makers, scholars, and funding organizations.

Appendix

Table A Reviews of collaborative learning and relevant topics

Dimension	Research topic	Reviewer(s) and year	Sample size	Methods	Review period	Main topics/findings
The whole field of collaborative learning	Collaborative learning	Manathunga and Hernández-Leo (2015)	100	Systematic review	2000–2013	Frequency of higher education institutions situated in the same location utilizing learning management systems, open and organized discourse, peer evaluation, and cooperative composition, as well as team establishment

Table A Reviews of collaborative learning and relevant topics

Dimension	Research topic	Reviewer(s) and year	Sample size	Methods	Review period	Main topics/findings
Collaborative learning in specific subject domains	Peer assessment in collaborative medical education	Lerchenfeldt et al. (2019)	31	Systematic review	1997–2017	Prevalence of problem- and team-based learning, peer feedback and its impact on professionalism
	Digital collaborative learning in nursing education	Männistö et al. (2020)	5	Systematic review	2003–2018	Findings: (1) digital collaborative learning increases learners' knowledge and nursing skills; (2) collaborative learning enhances learners' interaction and collaboration, problem-solving, learning satisfaction and motivation
	CSCL in programming education	Silva et al. (2020)	27	Systematic review	2015–2020	Topics: collaborative resources, features, outcomes, collaboration structure, collaboration measures
	Collaborative learning in robotics and programming education	de Carvalho and de Magalhães Netto (2020)	22	Systematic review	2014–2018	Topics: collaborative activities, technological resources, degrees and modalities, methodologies, and pedagogical concepts
	Computer-supported collaborative writing	Zhang et al. (2021a, b)	113	Systematic review	1998–2020	Findings: (1) preferences for meaning-cantered writing tasks and (2) heterogeneity in metrics for text measurement
	Collaborative learning in nurse education	Williamson et al. (2020)	14	Systematic review	2008–2018	Topics: effectiveness of collaborative learning in practice models
	Collaborative learning in higher nursing education	Zhang and Cui (2018)	29	Systematic review	1985–2017	Findings: (1) collaborative learning's prevalence in classroom instruction, clinical education and online education, (2) collaborative learning's usefulness for promoting nursing knowledge and skills, clinical competency, and group skills and learning behaviours (e.g., engagement, motivation, and self-confidence)

Table A Reviews of collaborative learning and relevant topics

Dimension	Research topic	Reviewer(s) and year	Sample size	Methods	Review period	Main topics/findings
Technology use in collaborative learning	Mobile-assisted collaborative learning	Fu and Hwang (2018)	90	Systematic review	2007–2016	Topics: research approaches, educational tools and environments, participants, areas of study, practical domains, methods for grouping and cooperative learning tactics, connections between learning approaches and evaluation challenges
	Cloud computing tools' use in blended collaborative learning	Al-Samarraie and Saeed (2018)	29	Systematic review	2006–2017	Topics: (1) cloud-computing tools and their features, (2) opportunities/challenges
Analysis methodological	Social network analysis in CSCL	Dado and Bodemer (2017)	89	Systematic review	1999–2017	Topics: (1) social network analysis in CSCL; (2) social network analysis's measures in relation to cognitive, social, and motivational outcomes
Characteristics of collaborative learning	Argumentation-based CSCL	Noroozi et al. (2012)	108	Systematic review	1995–2011	Topics: (1) student conditions, (2) learning environments, (3) learning processes, (4) relationships between CSCL and learning outcomes
	Teacher guidance in collaborative learning	van Leeuwen and Janssen (2019)	66	Systematic review	Till 2018	Topics: associations of instructors' guidance strategies during collaborative learning with learner interactions and outcomes
	Temporal aspects of CSCL	Lämsä et al. (2021)	78	Systematic review	2003–2019	Topics: key operations for analysing CSCL's temporal aspects
	Group formation techniques in CSCL	Maqtary et al.(2019)	30	Systematic review	2005–2015	Topics: effective attributes and techniques of group formation, 2) knowledge gaps and limitations

Table A Reviews of collaborative learning and relevant topics

Dimension	Research topic	Reviewer(s) and year	Sample size	Methods	Review period	Main topics/findings
Learner characteristics in collaborative learning	Affective states in CSCL	Reis et al. (2018)	58	Systematic review	Till 2018	Topics: affective states and socio-emotional factors in CSCL, research challenges/directions
	Individual preparation for collaborative learning	Mende et al. (2021)	20	Systematic review	1987–2017	Results: (1) individual preparation influences retrieval, inferencing, and referencing variedly; (2) generative preparation tasks and learners' cognitive group awareness enhances individual preparation's advantages for collaborations
	Emotional aspects for productive dialogues in CSCL	Silva and Ferreira (2021)	70	Systematic review	1989–2020	Results: (1) neglect of emotional dimensions; (2) negative emotional aspects impair motivation in collaborative activities; (3) empathy is seldom considered in CSCL

Funding Open access funding provided by The Hong Kong Polytechnic University

Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

Informed consent This article does not contain any studies with human participants performed by any of the authors.

References

Abdul Rabu, S. N., Mohamad, S. K., Awwad, S. A. B., Ismail, N. H. A., & Yeen, K. S. (2023). Effectiveness of inquiry-based learning with the aid of BLOSSOMS video on students' performance and motivation. *Education and Information Technologies*, *28*(9), 11469–11494. https://doi.org/10.1007/s10639-023-11616-9

Ahmad, K., Iqbal, W., El-Hassan, A., Qadir, J., Benhaddou, D., Ayyash, M., & Al-Fuqaha, A. (2023). Data-driven artificial intelligence in education: A comprehensive review. *IEEE Transactions on Learning Technologies*, *17*, 12–31. https://doi.org/10.1109/TLT.2023.3314610

Al-Rahmi, W. M., Yahaya, N., Alturki, U., Alrobai, A., Aldraiweesh, A. A., Alsayed, O., A., Kamin, Y. B. (2020). Social media–based collaborative learning: The effect on learning success with the moderating role of cyberstalking and cyberbullying. *Interactive Learning Environments*, *30*(8), 1434–1447. https://doi.org/10.1080/10494820.2020.1728342

Al-Samarraie, H., & Saeed, N. (2018). A systematic review of cloud computing tools for collaborative learning: Opportunities and challenges to the blended-learning environment. *Computers & Education*, *124*, 77–91. https://doi.org/10.1016/j.compedu.2018.05.016

Appel, H. B., Walsh, E., Marsh, T. E., & Brown, C. (2023). Supporting students' mental health and social emotional learning through community engagement and collaboration. *Educational Research*, *65*(3), 285–300. https://doi.org/10.1080/00131881.2023.2209097

Bastian, M., Heymann, S., & Jacomy, M. (2009). Gephi: An open source software for exploring and manipulating networks. *Proceedings of the International AAAI Conference on Web and Social Media*, *3*(1), 361–362. https://doi.org/10.1609/icwsm.v3i1.13937

Bergdahl, N. (2022). Engagement and disengagement in online learning. *Computers & Education*, *188*, 104561. https://doi.org/10.1016/j.compedu.2022.104561

Chen, X., Zou, D., Cheng, G., & Xie, H. (2020). Detecting latent topics and trends in educational technologies over four decades using structural topic modeling: A retrospective of all volumes of computer & education. *Computers & Education*, *155*, 103855. https://doi.org/10.1016/j.compedu.2020.103855

Chen, X., Zou, D., Xie, H., Cheng, G., & Liu, C. (2022). Two decades of artificial intelligence in education: Contributors, collaborations, research topics, challenges, and future directions. *Educational Technology & Society*, *25*(1), 28–47. https://doi.org/10.30191/ETS.202201_25(1).0003

Chen, X., Xie, H., Li, Z., Cheng, G., Leng, M., & Wang, F. L. (2023). Information fusion and artificial intelligence for smart healthcare: A bibliometric study. *Information Processing & Management*, *60*(1), 103113. https://doi.org/10.1016/j.ipm.2022.103113

Chen, X., Zou, D., Xie, H., & Wang, F. L. (2024). Technology-enhanced higher education: Text mining and bibliometrics. *Heliyon*, *10*(4), e25776. https://doi.org/10.1016/j.heliyon.2024.e25776

Cheng, M., Huang, W., & Hsu, M. (2020). Does emotion matter? An investigation into the relationship between emotions and science learning outcomes in a game-based learning environment. *British Journal of Educational Technology*, *51*(6), 2233–2251. https://doi.org/10.1111/bjet.12896

Dado, M., & Bodemer, D. (2017). A review of methodological applications of social network analysis in computer-supported collaborative learning. *Educational Research Review*, *22*, 159–180. https://doi.org/10.1016/j.edurev.2017.08.005

de Carvalho, J. M., & de Magalhães Netto, J. F. (2020). Currents trends in use of collaborative learning in teaching of robotics and programming–a systematic review of literature. In *2020 IEEE Frontiers in Education Conference (FIE)* (pp. 21–24). IEEE. https://doi.org/10.1109/FIE44824.2020.9273950

Duan, P., Wang, Y., & Yin, P. (2020). Remote sensing applications in monitoring of protected areas: A bibliometric analysis. *Remote Sensing*, *12*(5), 772. https://doi.org/10.3390/rs12050772

Dür, M., & Keller, L. (2019). Research collaboration of Austrian and Indian teenagers in the context of education for sustainable development. *Sustainability*, *11*(18), 5094. https://doi.org/10.3390/su11185094

ElSayary, A. (2024). An investigation of teachers' perceptions of using ChatGPT as a supporting tool for teaching and learning in the digital era. *Journal of Computer Assisted Learning*, *40*(3), 931–945. https://doi.org/10.1111/jcal.12926

Fernandez-Perez, V., & Martin-Rojas, R. (2022). Emotional competencies as drivers of management students' academic performance: The moderating effects of cooperative learning. *The International Journal of Management Education*, *20*(1), 100600. https://doi.org/10.1016/j.ijme.2022.100600

Ferreira, A. I., da Costa Ferreira, P., Cooper, C. L., & Oliveira, D. (2019). How daily negative affect and emotional exhaustion correlates with work engagement and presenteeism-constrained productivity. *International Journal of Stress Management*, *26*(3), 261–271. https://doi.org/10.1037/str0000114

Fu, Q. K., & Hwang, G. J. (2018). Trends in mobile technology-supported collaborative learning: A systematic review of journal publications from 2007 to 2016. *Computers & Education*, *119*, 129–143. https://doi.org/10.1016/j.compedu.2018.01.004

Guerrero Bote, V. P., Olmeda-Gómez, C., & de Moya-Anegón, F. (2013). Quantifying the benefits of international scientific collaboration. *Journal of the American Society for Information Science and Technology*, *64*(2), 392–404. https://doi.org/10.1002/asi.22754

Guo, Z., & Barmaki, R. (2020). Deep neural networks for collaborative learning analytics: Evaluating team collaborations using student gaze point prediction. *Australasian Journal of Educational Technology*, *36*(6), 53–71. https://doi.org/10.14742/ajet.6436

Hagqvist, P., Oikarainen, A., Tuomikoski, A. M., Juntunen, J., & Mikkonen, K. (2020). Clinical mentors' experiences of their intercultural communication competence in mentoring culturally and linguistically diverse nursing students: A qualitative study. *Nurse Education Today*, *87*, 104348. https://doi.org/10.1016/j.nedt.2020.104348

Han, X. (2020). Evolution of research topics in LIS between 1996 and 2019: An analysis based on latent dirichlet allocation topic model. *Scientometrics*, *125*(3), 2561–2595. https://doi.org/10.1007/s11192-020-03721-0

Hatton-Bowers, H., Clark, C., Parra, G., Calvi, J., Bird, M. Y., Avari, P., Foged, J., & Smith, J. (2023). Promising findings that the cultivating healthy intentional mindful educators' program (CHIME) strengthens early childhood teachers' emotional resources: An iterative study. *Early Childhood Education Journal*, *51*(7), 1291–1304. https://doi.org/10.1007/s10643-022-01386-3

Haynes, M., Brown, A., Nichols, K., & Parveen Musofer, R. (2023). Measurement of student attitudes to science and association with inquiry-based learning in regional schools. *International Journal of Science Education*, *45*(8), 593–612. https://doi.org/10.1080/09500693.2023.2168138

Hsu, Y. C., Ho, H. N. J., Tsai, C. C., Hwang, G. J., Chu, H. C., Wang, C. Y., & Chen, N. S. (2012). Research trends in technology-based learning from 2000 to 2009: A content analysis of publications in selected journals. *Journal of Educational Technology & Society*, *15*(2), 354–370. Retrieved from https://www.jstor.org/stable/jeductechsoci.15.2.354. Accessed January 6, 2024.

Järvelä, S., Nguyen, A., & Hadwin, A. (2023). Human and artificial intelligence collaboration for socially shared regulation in learning. *British Journal of Educational Technology*, *54*(5), 1057–1076. https://doi.org/10.1111/bjet.13325

Järvenoja, H., Järvelä, S., & Malmberg, J. (2020). Supporting groups' emotion and motivation regulation during collaborative learning. *Learning and Instruction*, *70*, 101090. https://doi.org/10.1016/j.learninstruc.2017.11.004

Jim, J. R., Talukder, M. A. R., Malakar, P., Kabir, M. M., Nur, K., & Mridha, M. F. (2024). Recent advancements and challenges of NLP-based sentiment analysis: A state-of-the-art review. *Natural Language Processing Journal*, *6*, 100059. https://doi.org/10.1016/j.nlp.2024.100059

Lämsä, J., Hämäläinen, R., Koskinen, P., Viiri, J., & Lampi, E. (2021). What do we do when we analyse the temporal aspects of computer-supported collaborative learning? A systematic literature review. *Educational Research Review*. https://doi.org/10.1016/j.edurev.2021.100387

Lerchenfeldt, S., Mi, M., & Eng, M. (2019). The utilization of peer feedback during collaborative learning in undergraduate medical education: A systematic review. *BMC Medical Education*, *19*(1), 321. https://doi.org/10.1186/s12909-019-1755-z

Maloney, L. M., Hakimi, M., Hays, T., Adachi, J., Chau, A., Esper, B. S., Koulouris, V., Kung, P., Meier, K. R., & Schum, R. S. (2022). Learning the Language of medical device innovation: A longitudinal interdisciplinary elective for medical students. *Academic Medicine*, *97*(9), 1341–1345. https://doi.org/10.1097/ACM.0000000000004723

Manathunga, K., & Hernández-Leo, D. (2015). Has research on collaborative learning technologies addressed massiveness? A literature review. *Journal of Educational Technology & Society*, *18*(4), 357–370. Retrieved from https://www.jstor.org/stable/jeductechsoci.18.4.357. Accessed January 6, 2024.

Manca, S., & Delfino, M. (2021). Adapting educational practices in emergency remote education: Continuity and change from a student perspective. *British Journal of Educational Technology*, *52*(4), 1394–1413. https://doi.org/10.1111/bjet.13098

Mann, H. B. (1945). Nonparametric tests against trend. *Econometrica: Journal of the Econometric Society*, *13*, 245–259. https://doi.org/10.2307/1907187

Männistö, M., Mikkonen, K., Kuivila, H., Virtanen, M., Kyngäs, H., & Kääriäinen, M. (2020). Digital collaborative learning in nursing education: A systematic review. *Scandinavian Journal of Caring Sciences*, *34*(2), 280–292. https://doi.org/10.1111/scs.12743

Mänty, K., Järvenoja, H., & Törmänen, T. (2020). Socio-emotional interaction in collaborative learning: Combining individual emotional experiences and group-level emotion regulation. *International Journal of Educational Research*, *102*, 101589. https://doi.org/10.1016/j.ijer.2020.101589

Mänty, K., Järvenoja, H., & Törmänen, T. (2023). The sequential composition of collaborative groups' emotion regulation in negative socio-emotional interactions. *European Journal of Psychology of Education*, *38*(1), 203–224. https://doi.org/10.1007/s10212-021-00589-3

Maqtary, N., Mohsen, A., & Bechkoum, K. (2019). Group formation techniques in computer-supported collaborative learning: A systematic literature review. *Technology Knowledge and Learning*, *24*(2), 169–190. https://doi.org/10.1007/s10758-017-9332-1

Marsh, E., Vallejos, E. P., & Spence, A. (2022). The digital workplace and its dark side: An integrative review. *Computers in Human Behavior*, *128*, 107118. https://doi.org/10.1016/j.chb.2021.107118

McMain, E. (2024). Getting good at bad emotion: Teachers resist and reproduce hegemonic positivity in a discourse community. *Critical Studies in Education*, *65*(1), 57–74. https://doi.org/10.1080/17508487.2023.2217867

Mende, S., Proske, A., & Narciss, S. (2021). Individual Preparation for collaborative learning: Systematic review and synthesis. *Educational Psychologist*, *56*(1), 29–53. https://doi.org/10.1080/00461520.2020.1828086

Meng, Y., Xu, W., Liu, Z., & Yu, Z. G. (2024). Scientometric analyses of digital inequity in education: Problems and solutions. *Humanities and Social Sciences Communications*, *11*(1), 1052. https://doi.org/10.1057/s41599-024-03480-w

Mertala, P., López-Pernas, S., Vartiainen, H., Saqr, M., & Tedre, M. (2024). Digital natives in the scientific literature: A topic modeling approach. *Computers in Human Behavior*, *152*, 108076. https://doi.org/10.1016/j.chb.2023.108076

Musick, G., Hauptman, A. I., Flathmann, C., McNeese, N. J., & Knijnenburg, B. P. (2023). Recommendations with benefits: Exploring explanations in information sharing recommender systems for temporary teams. *International Journal of Human–Computer Interaction*, *40*, 1–17. https://doi.org/10.1080/10447318.2023.2278933

Nguyen, P. M. B., Pham, X. L., & Truong, G. N. T. (2023). A bibliometric analysis of research on tourism content marketing: Background knowledge and thematic evolution. *Heliyon*. https://doi.org/10.1016/j.heliyon.2023.e13487

Noroozi, O., Weinberger, A., Biemans, H. J. A., Mulder, M., & Chizari, M. (2012). Argumentation-based computer supported collaborative learning (ABCSCL): A synthesis of 15 years of research. *Educational Research Review*, *7*(2), 79–106. https://doi.org/10.1016/j.edurev.2011.11.006

Ouyang, F., & Dai, X. (2022). Using a three-layered social-cognitive network analysis framework for understanding online collaborative discussions. *Australasian Journal of Educational Technology*, *38*(1), 164–181. https://doi.org/10.14742/ajet.7166

Padilla-Meléndez, A., Garrido-Moreno, A., & Del Aguila-Obra, A. R. (2008). Factors affecting e-collaboration technology use among management students. *Computers & Education*, *51*(2), 609–623. https://doi.org/10.1016/j.compedu.2007.06.013

Prestridge, S., & Cox, D. (2023). Play like a team in teams: A typology of online cognitive-social learning engagement. *Active Learning in Higher Education*, *24*(1), 3–20. https://doi.org/10.1177/1469787421990986

Rashid, M., Nguyen, J., Foulds, J. L., & Forgie, S. E. (2023). Exploring virtual teaching approaches among pediatricians during the SARS-CoV-2 pandemic: A virtual ethnographic study. *Journal of Continuing Education in the Health Professions*, *43*(1), 12–20. https://doi.org/10.1097/CEH.0000000000000449

Rasi, P., & Vuojärvi, H. (2018). Toward personal and emotional connectivity in mobile higher education through asynchronous formative audio feedback. *British Journal of Educational Technology*, *49*(2), 292–304. https://doi.org/10.1111/bjet.12587

Reis, R. C. D., Isotani, S., Rodriguez, C. L., Lyra, K. T., Jaques, P. A., & Bittencourt, I. I. (2018). Affective states in computer-supported collaborative learning: Studying the past to drive the future. *Computers & Education*, *120*, 29–50. https://doi.org/10.1016/j.compedu.2018.01.015

Roberts, M. E., Stewart, B. M., Tingley, D., Lucas, C., Leder-Luis, J., Gadarian, S. K., Albertson, B., & Rand, D. G. (2014). Structural topic models for open-ended survey responses. *American Journal of Political Science*, *58*(4), 1064–1082. https://doi.org/10.1111/ajps.12103

Roberts, M. E., Stewart, B. M., & Tingley, D. (2019). Stm: An R package for structural topic models. *Journal of Statistical Software*, *91*, 1–40. https://doi.org/10.18637/jss.v091.i02

Rothstein, R., Lee, Y., Berger, E. J., Rhoads, J., & Deboer, J. (2023). Collaborative engagement and help-seeking behaviors in engineering asynchronous online discussions. *International Journal of Engineering Education*, *39*(1), 189–207. Retrieved from https://www.ijee.ie/1atestissues/Vol39-1/17_ijee4302.pdf.. Accessed January 6, 2024.

Ruzek, E. A., Hafen, C. A., Allen, J. P., Gregory, A., Mikami, A. Y., & Pianta, R. C. (2016). How teacher emotional support motivates students: The mediating roles of perceived peer relatedness, autonomy support, and competence. *Learning and Instruction*, *42*, 95–103. https://doi.org/10.1016/j.learninstruc.2016.01.004

Samsul, S. A., Yahaya, N., & Abuhassna, H. (2023). Education big data and learning analytics: A bibliometric analysis. *Humanities and Social Sciences Communications*, *10*(1), 709. https://doi.org/10.1057/s41599-023-02176-x

Sarwar, B., Zulfiqar, S., Aziz, S., & Ejaz Chandia, K. (2019). Usage of social media tools for collaborative learning: The effect on learning success with the moderating role of cyberbullying. *Journal of Educational Computing Research*, *57*(1), 246–279. https://doi.org/10.1177/0735633117748415

Schultz, L. M., Bonney, E. N., Dorner, L. M., & Song, K. (2023). From attendance to collaboration: Contextual differences in teacher perceptions of multilingual family engagement. *Teachers College Record*, *125*(1), 132–162. https://doi.org/10.1177/01614681231155698

Silva, U. F., & Ferreira, D. J. (2021). Emotional aspects for productive dialogues in computer-supported collaborative learning: A systematic literature review. *JUCS-Journal of Universal Computer Science*, *27*, 303–322. https://doi.org/10.3897/jucs.66389

Silva, L., Mendes, A. J., & Gomes, A. (2020). Computer-supported collaborative learning in programming education: A systematic literature review. In *2020 IEEE Global Engineering Education Conference (EDUCON)* (pp. 1086–1095). IEEE. https://doi.org/10.1109/EDUCON45650.2020.9125237

Sonnenwald, D. H. (2007). Scientifc collaboration. *Annual Review of Information Science and Technology*, *41*(1), 643–681. https://doi.org/10.1002/aris.2007.1440410121

Strauß, S., & Rummel, N. (2021). Promoting regulation of equal participation in online collaboration by combining a group awareness tool and adaptive prompts. But does it even matter? *International Journal of Computer-Supported Collaborative Learning*, *16*(1), 67–104. https://doi.org/10.1007/s11412-021-09340-y

Taheri, H., Sadighi, F., Bagheri, M. S., & Bavali, M. (2019). EFL learners' L2 achievement and its relationship with cognitive intelligence, emotional intelligence, learning styles, and Language learning strategies. *Cogent Education*, *6*(1), 1655882. https://doi.org/10.1080/2331186X.2019.1655882

Tan, S. E., & Jung, I. (2024). Unveiling the dynamics and impact of emotional presence in collaborative learning. *International Journal of Educational Technology in Higher Education*, *21*(1), 44. https://doi.org/10.1186/s41239-024-00477-y

Tan, S. C., Lee, A. V. Y., & Lee, M. (2022). A systematic review of artificial intelligence techniques for collaborative learning over the past two decades. *Computers and Education: Artificial Intelligence*, *3*, 100097. https://doi.org/10.1016/j.caeai.2022.100097

Tang, H., Arslan, O., Xing, W., & Kamali-Arslantas, T. (2023). Exploring collaborative problem solving in virtual laboratories: A perspective of socially shared metacognition. *Journal of Computing in Higher Education*, *35*, 296–319. https://doi.org/10.1007/s12528-022-09318-1

Törmänen, T., Järvenoja, H., Saqr, M., Malmberg, J., & Järvelä, S. (2023). Affective states and regulation of learning during socio-emotional interactions in secondary school collaborative groups. *British Journal of Educational Psychology*, *93*, 48–70. https://doi.org/10.1111/bjep.12525

van Leeuwen, A., & Janssen, J. (2019). A systematic review of teacher guidance during collaborative learning in primary and secondary education. *Educational Research Review*, *27*, 71–89. https://doi.org/10.1016/j.edurev.2019.02.001

Williamson, G. R., Plowright, H., Kane, A., Bunce, J., Clarke, D., & Jamison, C. (2020). Collaborative learning in practice: A systematic review and narrative synthesis of the research evidence in nurse education. *Nurse Education in Practice*, *43*, 102706. https://doi.org/10.1016/j.nepr.2020.102706

Yadegaridehkordi, E., Noor, N. F. B. M., Ayub, M. N., Bin, Affal, H. B., & Hussin, N. B. (2019). Affective computing in education: A systematic review and future research. *Computers & Education*, *142*, 103649. https://doi.org/10.1016/j.compedu.2019.103649

Yildiz Durak, H., & Atman Uslu, N. (2023). Group regulation guidance through agile learning strategies: Empowering co-regulation, transactive memory, group cohesion, atmosphere, and participation. *Educational Technology Research and Development*, *71*(4), 1653–1685. https://doi.org/10.1007/s11423-023-10237-w

Zhang, J., & Cui, Q. (2018). Collaborative learning in higher nursing education: A systematic review. *Journal of Professional Nursing*, *34*(5), 378–388.

Zhang, Z., & Gao, X. A. (2024). A longitudinal study of enjoyment and group-level emotion regulation in online collaborative English language learning. *Learning and Motivation*, *88*, 102052. https://doi.org/10.1016/j.lmot.2024.102052

Zhang, E. D., & Yu, S. (2024). Understanding L2 student writers' self-assessment in digital multimodal composing: A process-oriented approach. *System*, *121*, 103219. https://doi.org/10.1016/j.system.2024.103219

Zhang, M., Gibbons, J., & Li, M. (2021a). Computer-mediated collaborative writing in L2 classrooms: A systematic review. *Journal of Second Language Writing*, *54*, 100854. https://doi.org/10.1016/j.jslw.2021.100854

Zhang, Z., Liu, T., & Lee, C. B. (2021b). Language learners' enjoyment and emotion regulation in online collaborative learning. *System*, *98*, 102478. https://doi.org/10.1016/j.system.2021.102478

Zou, D., Xie, H., & Wang, F. L. (2023). Effects of technology enhanced peer, teacher and self-feedback on students' collaborative writing, critical thinking tendency and engagement in learning. *Journal of Computing in Higher Education*, *35*(1), 166–185. https://doi.org/10.1007/s12528-022-09337-y

Xieling Chen is an associate professor at School of Education, Guangzhou University, Guangzhou, China. Her research interests include educational technology, bibliometric analysis, and AI in education.

Di Zou is an Associate Professor in the Department of English and Communication at The Hong Kong Polytechnic University. Her research interests include AI in language education, technology-enhanced language learning, and game-based language learning. She has published more than 150 papers in international journals. Stanford University listed her as one of the World's Top 2% Most-cited Scientists since 2021 for 4 years.

Lucas Kohnke is a Senior lecturer at Department of English Language Education, The Education University of Hong Kong, Hong Kong SAR. His research interests include AI in language education, technology-enhanced language learning, and teacher training.

Haoran Xie is a Professor and the Person-in-Charge of Division of Artificial Intelligence, the Acting Associate Dean of School of Data Science, and the Director of LEO Dr. David P. Chan Institute of Data Science at Lingnan University, Hong Kong. He is the Editor-in-Chief of Natural Language Processing Journal (Elsevier), Computers & Education: Artificial Intelligence (Elsevier), and Computers & Education: X Reality (Elsevier), Co-Editor-in-Chief of Knowledge Management and E-Learning (HKU) the Associate Editor of International Journal of Machine Learning and Cybernetics (Springer), Array (Elseiver), International Journal of Mobile Learning and Organisation (InderScience).

Gary Cheng is the Executive Co-Director of the Centre for Learning, Teaching and Technology (LTTC) and an Associate Professor of the Department of Mathematics and Information Technology at The Education University of Hong Kong (EdUHK). His academic background is in computer science, but he has specialised in teaching Information and Communication Technology (ICT) in education for over 15 years. With substantial years of work experience in Hong Kong academia, Dr Cheng has built a wealth of knowledge and a network of support to unleash the potential of technology for teacher education. He has a proven track record of exploring and evaluating the use of emerging technologies to enhance teaching and learning.

Fu Lee Wang is currently a Professor and the Dean of Science and Technology at Hong Kong Metropolitan University. He obtained his Bachelor of Engineering in Computer Engineering and Master of Philosophy in Computer Science and Information Systems from The University of Hong Kong, Master of Business Administration from Imperial College London, Master of Science in Mathematics (Financial Mathematics and Statistics) from The Hong Kong University of Science and Technology, and a Doctor of Philosophy in Systems Engineering and Engineering Management from The Chinese University of Hong Kong.

Authors and Affiliations

Xieling Chen[1] · Di Zou[2] · Lucas Kohnke[3] · Haoran Xie[4] · Gary Cheng[5] · Fu Lee Wang[6]

✉ Di Zou
daisy.zou@polyu.edu.hk

Xieling Chen
chenxieling@gzhu.edu.cn

Lucas Kohnke
lmakohnke@eduhk.hk

Haoran Xie
hrxie@ln.edu.hk

Gary Cheng
chengks@eduhk.hk

Fu Lee Wang
pwang@hkmu.edu.hk

1 School of Education, Guangzhou University, Guangzhou, China

2 Department of English and Communication, The Hong Kong Polytechnic University, Hong Kong, SAR, China

3 Department of English Language Education, The Education University of Hong Kong, Hong Kong, SAR, China

4 School of Data Science, Lingnan University, Hong Kong, SAR, China

5 Department of Mathematics and Information Technology, The Education University of Hong Kong, Hong Kong, SAR, China

6 School of Science and Technology, Hong Kong Metropolitan University, Hong Kong, SAR, China