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Science mapping the knowledge base on microlearning: using Scopus database between 2002 and 2021

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Received 16 September 2023
Revised 18 December 2023
8 February 2024
Accepted 10 March 2024

Abstract

Purpose – With the advancement of technology, microlearning has emerged as a promising method to improve the efficacy of teaching and learning. This study aims to investigate the document types, volume, growth trajectory, geographic contribution, coauthor relationships, prominent authors, research groups, influential documents and publication outlets in the microlearning literature.

Design/methodology/approach – We adapt the PRISMA guidelines to assess the eligibility of 297 Scopus-indexed documents from 2002 to 2021. Each was manually labeled by educational level. Descriptive statistics and science mapping were conducted to highlight relevant objects and their patterns in the knowledge base.

Findings – This study confirms the increasing trend of microlearning publications over the last two decades, with conference papers dominating the microlearning literature (178 documents, 59.86%). Despite global contributions, a concentrated effort from scholars in 15 countries (22.39%) yielded 68.8% of all documents, while the remaining papers were dispersed across 52 other nations (77.61%). Another significant finding is that most documents pertain to three educational level categories: lifelong learning, higher education and all educational levels. In addition, this research highlights six key themes in the microlearning domain, encompassing (1) Design and evaluation of mobile learning, (2) Microlearning adaptation in MOOCs, (3) Language teaching and learning, (4) Workflow of a microlearning system, (5) Microlearning content design, (6) Health competence and health behaviors. Other aspects analyzed in this study include the most prominent authors, research groups, documents and references.

This research is funded by the Vietnam National Foundation for Science and Technol-ogy Development (NAFOSTED) under the National Research Grant No. 503.01-2023.08.

Journal of Research in Innovative Teaching & Learning
Emerald Publishing Limited
2397-7604
DOI 10.1108/JRIT-09-2023-0132

Originality/value – The finding represents all topics at various educational levels to offer a comprehensive view of the knowledge base.

Keywords Microlearning, Bibliometric analysis, Science mapping, Scientometrics, 2-mode analysis
Paper type Research paper

Introduction

Microlearning is one of the most innovative approaches to teaching and learning that has emerged in the past decade (Leong *et al.*, 2020). Despite having different conceptualizations, the following features are often identified as typical characteristics of microlearning: (1) short learning components with short content, tables, figures and/or videos; (2) short-term focused and interactive activities; (3) mono learning outcome oriented (Aldosemani, 2019; Leong *et al.*, 2020).

Based on Spaced Learning Theory, microlearning has demonstrated its effectiveness in helping learners to have a longer-term memory than the traditional learning method (Smolen *et al.*, 2016.,). Scholars like Giurgiu (2017) and Shail (2019) agree that microlearning facilitates improved conceptual retention. Beyond memory enhancement, previous empirical studies offer a broader perspective on the advantages of microlearning. Ozer *et al.* (2017) and Mohammed *et al.* (2018) found that microlearning content propels enhanced comprehension and application of knowledge, leading to improved academic achievement. Moreover, Nikou and Economides (2018) shed light on the time flexibility inherent in microlearning, allowing learners to navigate content any time at their own pace, thereby fostering a personalized and adaptable learning experience. Other advantages of microlearning have also been revealed, such as improving learners' motivation (Nikou and Economides, 2018; Shail, 2019), increasing learners' engagement (De Gagne *et al.*, 2019), and facilitating ubiquitous learning (Mohammed *et al.*, 2018).

Although a microlearning lecture can be delivered in full offline mode, most microlearning practitioners prefer to adapt microlearning to their digital online platforms (Inker *et al.*, 2021). Specifically, a microlearning lesson might be part of a blended learning course, assessed on various devices, such as computer, laptop, tablet, or mobile phone. In some other cases, microlearning could be integrated with gamification to become gamified microlearning (Septiani and Rosmansyah, 2021).

Regarding microlearning learners, in the beginning, microlearning was explicitly used for corporate training for corporate employees (Gabrielli *et al.*, 2005). Over time, microlearning learners have been extended to aging people (Gómez *et al.*, 2021; Simons *et al.*, 2015), undergraduate students (Gill *et al.*, 2020), vocational students (Billert *et al.*, 2022), and also K-12 students (Nikou and Economides, 2018). Microlearning has been adopted in not only developed countries such as European countries (European Commission, 2020), Australia (Alex *et al.*, 2022) and the US (Triana *et al.*, 2021) but also in developing countries such as China (Yin *et al.*, 2021) and Malaysia (Kumar *et al.*, 2022). Along with the rise of microlearning in actual practice, education researchers have also paid increasing attention to this topic. Notably, some authors have tried to conduct systematic views on the topic of microlearning using the bibliometric approach, including Sankaranarayanan *et al.* (2023), Kuzminska *et al.* (2022), and Leong *et al.* (2020).

Nevertheless, these works still bear several limitations for further improvement. Specifically, Sankaranarayanan *et al.* (2023) and Leong *et al.* (2020) only use bibliometric indicators to produce descriptive analysis, not science mapping analysis. Meanwhile, the work of Kuzminska *et al.* (2022) does not have this caveat, but the concern is that it only focuses on the science mapping of co-keyword analysis. In this study, we address the limitations faced by previous bibliometric analyzes of microlearning studies. Thus, in this study, both descriptive analysis and science mapping will be performed. Specifically, in science mapping analysis, co-keyword analysis and others, such as co-author analysis and co-citation analysis, would be performed. Furthermore, apart from the set of keywords obtained from the Scopus database, we also manually created a new set of keywords according to the educational levels of respective studies. The new set of keywords would be combined with Scopus's set of keywords to perform a 2-mode science mapping analysis. With a 2-mode analysis, we expect a more insightful picture of the extant literature on microlearning studies. Our study intends to seek answers to the following research questions (RQs):

RQ1. What are the types, volume, and growth trajectory of microlearning research publications?

RQ2. What is the geographic distribution of publications and international collaborations between authors in this field?

RQ3. Which are the most influential authors, research groups, documents, themes and sources of microlearning publications?

RQ4. What are the educational levels in microlearning research, the number of documents in each, and their associations with keywords?

Method

The bibliometric analysis introduced by Pritchard (1969) was selected to conduct this study. The bibliometric analysis combines descriptive and science mapping analysis (Hallinger and Kovačević, 2023) and could be used to explore a knowledge base by synthesizing patterns from earlier literature; therefore, many previous studies in various fields have employed this method (Methlagl, 2022; Hallinger and Kovačević, 2022). In educational research, bibliometric analysis has been applied at various educational levels, such as primary education (e.g. see Aktoprak and Hursen, 2022), higher education (e.g. see Hallinger and Chatpinyakoop, 2019; Pham *et al.*, 2021), lifelong learning (e.g. see Do *et al.*, 2021), and in many education topics, such as learning and teaching (e.g. Karakus *et al.*, 2021), management (e.g. Hallinger and Kovačević, 2022).

Bibliographic data is required for bibliometric analysis. Web of Science (WoS) and Scopus are the two most prominent academic databases. According to Hallinger (2019), Scopus is far more comprehensive than WoS in educational research. Additionally, Tabacaru (2019) asserted that Scopus records books and book chapters more accurately than WoS. Meanwhile, books and book chapters are essential in social sciences, including education (Pham *et al.*, 2021). Therefore, Scopus was selected as the data source for this study.

Based on the research's scope, we used microlearning and its variants (such as microlearning, micro-learning) as the primary keywords. We put them within the "title, abstract, and keyword" fields on the Scopus search engine. Specifically, the search query as follows was conducted at 15h00 on 28 August 2022:

TITLE-ABS-KEY ("microlearning" OR "micro-learning" OR "micro-learning") AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "ch") OR LIMIT-TO (DOCTYPE, "bk")) AND (LIMIT-TO (LANGUAGE, "English")) AND (EXCLUDE (PUBYEAR, 2022)).

Initially, we obtained 464 documents. To refine this raw data, we followed two steps in PRISMA guidelines (Moher *et al.*, 2009), as shown in Figure 1.

First, in the screening phase, the included criteria are limited as follows: (1) social sciences areas, (2) English language, (3) final publication stage, and (4) four document types (article, conference paper, book, and book chapter). This step yielded 322 documents for further analysis.

Second, in the eligibility phase, we assigned two co-authors of this paper to thoroughly read the abstracts and the full texts (if necessary). After this step, the two co-authors of this paper agreed that 25 did not belong to the scope of the investigation (e.g. Horst *et al.*, 2019; Muscat *et al.*, 2021), and, thus, were eliminated. Eventually, we will have 297 documents for final analysis.

Particularly, we downloaded their bibliographic information in text and Excel formats. Each document includes details regarding its year of publication, type of document, co-author's name, co-author's affiliation, source of publication, number of citations, keywords, and references.

Apart from keywords obtained from Scopus, each document was also given another set of keywords according to its education level: HE (higher education), GE (general education), LLL (lifelong learning), ECE (early childhood education), TVET (technical and vocational education and training), and All levels (covering all educational levels). This new set of keywords was assigned manually by the two co-authors of this paper during the eligibility phase, as mentioned above.

To address the research questions, we used descriptive analysis and science mapping. Several software, including Excel, R, VOSViewer (https://www.vosviewer.com/) and Gephi (<u>https://gephi.org/), were employed for data visualization.

Results and discussion

Document types, volume and growth trajectory

From the Scopus database, we identified 297 documents that were published between 2002 and 2021. Conference papers share the most enormous "pie" with 178 documents (or 59.86%). Followed by conference papers are journal articles with 108 documents (36.4%). Other document types contribute insignificantly to the studied topic, with only ten book chapters (3.4%) and one book (0.34%). In terms of timeline, the earliest publication on microlearning in our database is entitled "*Lifelong training using Vincent, a web-based pedagogical agent*," published in 2002 by Ana Paiva and Isabel Machado. The first three papers on microlearning are journal articles published in 2002, 2003, and 2005, respectively (see Paiva and Machado, 2002; Schwen and Hara, 2003; Ali and Laskri, 2005). During the subsequent 14-year span from 2007 to 2020, conference papers consistently constituted the majority of microlearning documents (see Figure 2). In 2021, for the first time, the number of published journal articles (31 documents) exceeded that of conference papers (24 documents). The finding that conference papers dominate the overall studies on microlearning bears several implications as it is not in line with many other bibliometric analyses in education research, which found journal articles as primary sources (Do *et al.*, 2021; Pham *et al.*, 2021). On the one hand, this finding reflects the nature of microlearning as a rapidly emerging topic that receives

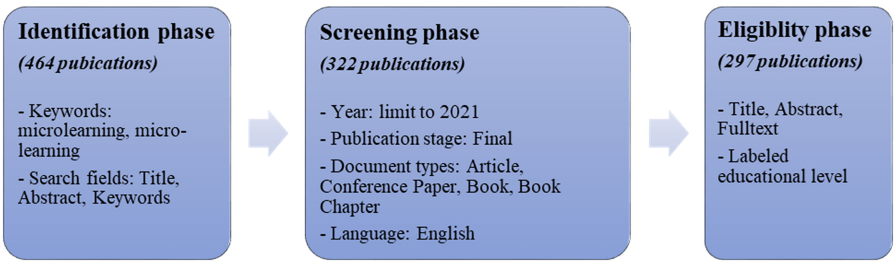

Figure 1.
Data gathering process followed by PRISMA guideline

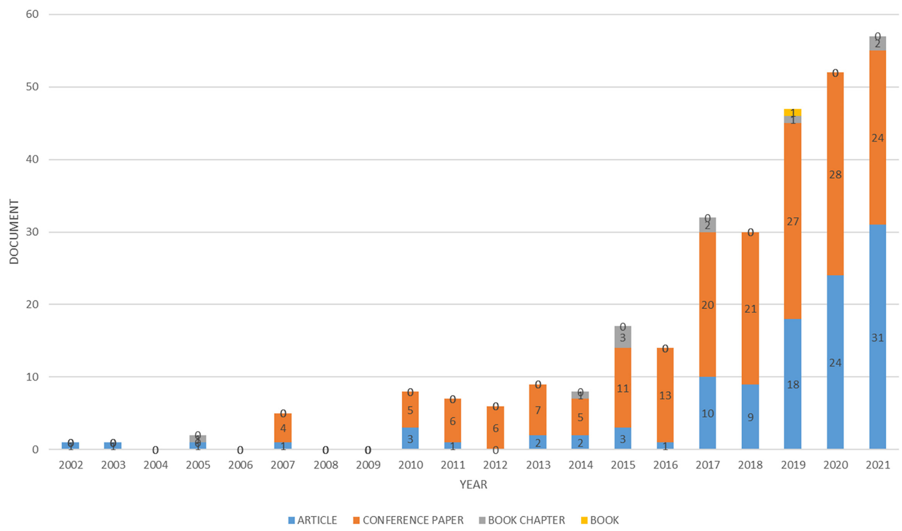

Figure 2.
The growth trajectory of microlearning research between 2002 and 2021

significant attention from scholars in various fields. On the other hand, a possible explanation for this finding is that many microlearning authors come from fields with a tradition of favoring conference publishing rather than journals such as computer science or information technology (e.g. Dhinakaran *et al.*, 2021; Lin *et al.*, 2020; Zhang, 2021).

As shown in Figure 2, the growth rate of publications in this knowledge base was modest and largely flat between 2002 and 2014. During this period, less than ten publications were produced each year. The number of microlearning documents reached the two-digit mark for the first time in 2015 with 17 documents. In the subsequent year, microlearning publications decreased slightly to 14 documents. The average number of publications in the following two years was twice that of the prior period. From 2019 to 2021, there was an average of 50 publications per year, presenting a considerable increase compared to 2018 backwards. The growth of microlearning research from 2019 onward reflects its intertwinement with the advancement of educational technology such as online learning, MOOCs (Goodell *et al.*, 2021), blended learning (Leyendecker and Zagel, 2021; Yang, 2020), gamification (Levi *et al.*, 2021; Gough *et al.*, 2021), a chatbot (Yin *et al.*, 2021), virtual learning (Dhinakaran *et al.*, 2021). As illustrated in Figure 2, the surge in microlearning studies since 2019 seems to be attributed to the remarkable contribution of journal articles. In the retrospective analysis spanning from 2018 and earlier, the quantity of microlearning-related journal articles consistently lagged behind the corresponding figures for conference papers. However, in 2019 and 2020, there is evidence of a more equitable distribution, as reflected in the ratios of the number of journal articles to the number of conference papers. Notably, in 2021, a significant milestone was reached, with the number of journal articles surpassing that of conference papers for the first time in the observed period.

Geographic distribution and international collaborations

Figure 3 shows a heat map of the number of papers published by 67 countries based on the national affiliation of all 297 publications. Specifically, scholars from the US and China are the leading contributors, with 55 documents (15.11%) and 50 documents (13.74%), respectively. Authors from Germany are similarly active in this field of study with 29 documents (7.97%),

Figure 3.
The geographical distribution of microlearning publications

followed by Australia with 24 documents (6.59%) and Austria with 15 documents (4.12%). Although the topic has a significantly wide geographical breadth of authorship, there needs to be a bigger gap in the number of documents published by different nations. Twenty-three out of 67 nations (34.33%) had only one paper, and twenty-nine of those countries (43.28%) published between two and five papers. In contrast, the remaining 15 nations (22.39%) contributed 250 papers, accounting for 68.8% of all microlearning publications.

Figure 4 shows the collaboration network of 35 countries between 2002 and 2021, in which each country has at least one microlearning document. Each node on the map represents a country, and link strength reflects the total number of co-authorships between the two depicted countries.

Countries with the highest levels of cooperation include the US, with 11 links (i.e. co-authoring with 11 countries) and 23 total link strength (i.e. 23 times co-authoring with other countries); Spain (ten links, 11 total link strength); Austria (eight links, 11 total link strength); Poland (8 links, ten total link strength); China (seven links, 21 total link strength); and Australia (six links, 15 total link strength).

The case of Austria provides an interesting finding which is needed for further investigation. As shown in Figure 4, although it is not the largest node, Austria is positioned at the center of the map, connecting with two clusters: the larger one on the left and the

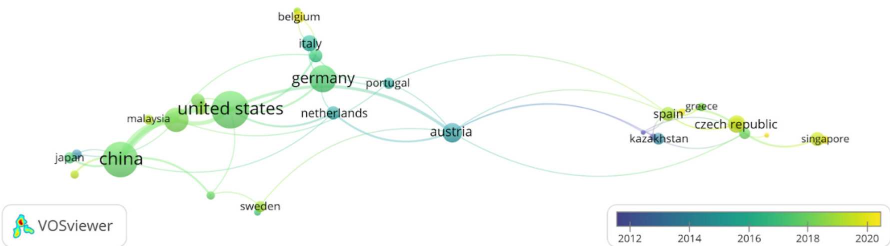

Figure 4.
Co-author collaboration network by country from microlearning publications

smaller one on the right side. In terms of timeline, scholars from the US published their first document on microlearning in 2003 (see Schwen and Hara, 2003) far before other highly productive countries such as Austria (first paper published in 2006 by Gstrein and Hug, 2006) or China (first paper published in 2010 by Zhao *et al.*, 2010).

A closer look at the list of documents published by scholars from Austria unveils the role of an institution, namely *Research Studios Austria Forschungsgesellschaft* (RSA FG). Specifically, the pioneering role of this institution is two-fold. First, RSA FG hosted several international conferences on microlearning between 2005 and 2016 (e.g. Bruck *et al.*, 2012; Göschlberger and Anderst-Kotsis, 2019). Second, scholars from RSA FG also contributed several documents (precisely nine documents) on microlearning between 2006 and 2019 (e.g. Gstrein and Hug, 2006; Göschlberger *et al.*, 2019). Nevertheless, it appears that RSA FG has ceased its interest in microlearning since 2019, as it was the last year that authors of RSA FG published a microlearning-related document (see Göschlberger and Anderst-Kotsis, 2019).

The influential authors

The authors' rankings according to the number of publications and total citations were analyzed to identify the most productive authors and their impacts. As seen in Table 2, all 10 top authors published their documents recently (since 2015). Cui T (the University of Melbourne, Melbourne, Australia), Shen J (University of Wollongong, Australia), and Sun G (University of Wollongong, Australia) are the top three authors in terms of number of publications, each having 20 publications. In fourth place is Xu D (the University of Hong Kong), with 15 publications, followed by Chen S (Australia's CSIRO Data61, 14 publications) and Lin J (China's Shanghai University of Medicine and Health Sciences, 10 publications). Besides, our empirical data reveal that the top three authors in terms of the number of citations are: Cui T, Shen J and Sun G. Specifically, each of the three authors received 177 citations, followed by Chen S in fourth place with 144 citations. Although not among the top 10 authors in total publications, Edge D (Microsoft Research Asia in Beijing, China) is recognized as the fifth most cited author. All in all, Cui T, Shen J, Sun G, Chen S, and Xu D are the five scholars who rank in both leagues. In addition, ten others only appear in one of the two leagues (see Table 1).

Among these two leagues of high-profile authors of microlearning, the appearance of two authors from the industry sector (Chen S from Australia's CSIRO Data61 and Edge D from Microsoft Research Asia in Beijing) is attractive as it implies that microlearning does not only appeal to attention from academia but also from researchers and practitioners from the educational technology industry. This finding may also illustrate that the origin of microlearning lies in corporate training rather than formal education, as explained from the outset of this paper (Gabrielli *et al.*, 2005).

Research groups

Our empirical data show that 733 authors have contributed to at least one publication on microlearning. Among them, 48 authors have published independently as solo authors, while 685 scholars have co-authors. These 685 scholars have formed 201 distinct clusters or research teams, with the largest one constituting 17 members (led by Cui T as seen in Figure 5). Zhang Y leads the second largest cluster with 15 members, followed by the 14-member cluster led by Ritter M. Most of the other research groups have fewer than 10 members (see Figure 5). In terms of timeline, a majority of newly established teams (colored in yellow) have emerged in recent years (e.g. Yu B's, and Li M's); meanwhile, several traditional teams (colored dark green or purple) are no longer active (e.g. Liu Cm', Lella L's, and Mercurio M's). Notably, we reveal five research groups (led by Cui T, Zhu C, Zhaparov M, Li X and Bruck PA) with their members in three colors (i.e. purple, green and yellow). These groups are

Top publications				Top citations			
ID	Author (affiliation)	NP	Period	ID	Author (affiliation)	TC	Period
1	Cui T (University of Melbourne, Australia)	20	2015–2020	1	Cui T (University of Melbourne, Australia)	177	2015–2020
2	Shen J (University of Wollongong, Australia)	20	2015–2020	2	Shen J (University of Wollongong, Australia)	177	2015–2020
3	Sun G (University of Wollongong, Australia)	20	2015–2020	3	Sun G (University of Wollongong, Australia)	177	2015–2020
4	Xu D (University of Hong Kong, Hong Kong)	15	2015–2020	4	Chen S (CSIRO Data61, Australia)	144	2015–2020
5	Chen S (CSIRO Data61, Australia)	14	2015–2020	5	Edge D (Microsoft Research Asia, Beijing, China)	121	2011–2012
6	Lin J (Shanghai University of Medicine and Health Sciences, China)	10	2018–2021	6	Bruck Pa Research Studios Austria FG, Austria	109	2012–2017
7	Beydoun G (University of Technology Sydney, Australia)	9	2015–2020	7	Xu D (University of Hong Kong, Hong Kong)	100	2015–2020
8	Zhang Y (University of Nottingham Ningbo China, China)	6	2016–2020	8	Zhao J (Shanghai University of Medicine and Health Sciences, China)	91	2011–2021
9	Skalka J (Constantine the Philosopher University, Slovakia)	6	2018–2021	9	Foerster F (Georgia Institute of Technology, United States)	90	2012–2015
10	Li L (Southwest University, Chongqing, China)	5	2019–2020	10	Motiwalla L (University of Massachusetts Lowell, the US)	90	2012–2015

Note(s): TC and NP denote total citations and number of publications, respectively

Table 1.
Top 10 most important authors according to the number of publications and total citations

among the most traditional groups with more than 10 years of experience in microlearning research and are still active recently (i.e. having microlearning publications over the previous three years).

Influential documents

Table 2 presents the top 10 documents on microlearning ranked by local citations, of which six are conference papers whereas six are journal articles. This finding reflects the nature of microlearning as a newly emerging topic in which conference papers but not journal articles dominate the top cited documents.

The most cited document is a conference paper, entitled "*Mobile Learning with Micro-Content: A Framework and Evaluation*" by Bruck *et al.* (2012), with 26 local citations. The second-placed publication was authored by Kovachev *et al.* (2011), with 17 local citations. Subsequently, Sun *et al.* (2015) and Edge *et al.* (2011) share the third position with 13 citations each.

Among the most cited articles, papers with a focus on *e-learning* and *mobile learning* are prominent (e.g. Bruck *et al.*, 2012; Kovachev *et al.*, 2011; Sun *et al.*, 2015; Edge *et al.*, 2011;

Table 2. Top 10 documents ranked by local citations

ID	Document	Title	Document type	LC	GC	YP
1	Bruck *et al.* (2012)	Mobile Learning with Micro-content: A Framework and Evaluation	Conference Paper	26	58	2012
2	Kovachev *et al.* (2011)	Learn-as-you-go: new ways of cloud-based micro-learning for the mobile web	Conference Paper	17	44	2011
3	Sun *et al.* (2015)	Micro learning adaptation in MOOC: A software as a service and a personalized learner model	Conference Paper	13	20	2015
4	Edge *et al.* (2011)	MicroMandarin: mobile language learning in context	Conference Paper	13	89	2011
5	Beaudin *et al.* (2007)	Context-sensitive microlearning of foreign language vocabulary on a mobile device	Conference Paper	12	42	2007
6	Nikou and Economides (2018)	Mobile-Based micro-Learning and Assessment: Impact on learning performance and motivation of high school students	Journal Article	10	63	2018
7	Sun *et al.* (2018)	MLaaS: a cloud-based system for delivering adapative micro learning in mobile MOOC learning	Journal Article	7	41	2018
8	Göschlberger and Bruck (2017)	Co-Creation of Micro-Content Types	Conference Paper	7	19	2017
9	Sun *et al.* (2017)	Towards massive data and sparse data in adaptive micro open educational resource recommendation: a study on semantic knowledge base construction and cold start problem	Journal Article	7	21	2017
10	Simons *et al.* (2015)	Microlearning mApp raises health competence: hybrid service design	Journal Article	7	25	2015

Note(s): LC – Local Citations; GC – Global Citations; YP – Year of Publication

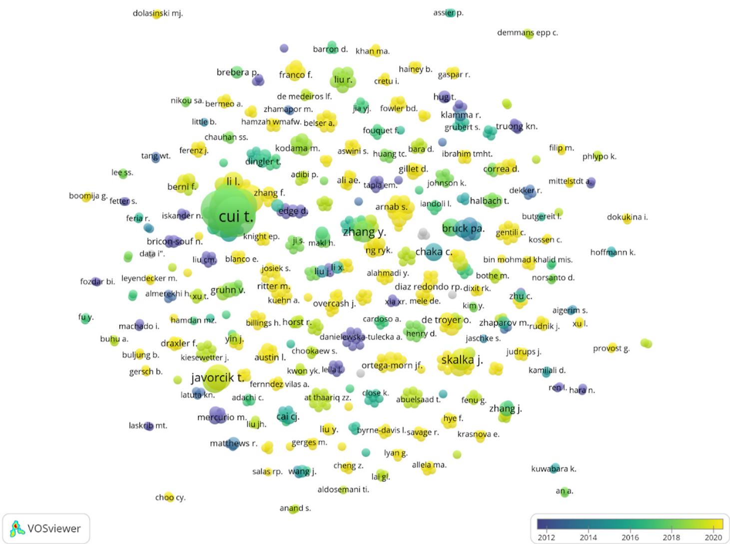

Figure 5. Research groups of microlearning research

Beaudin *et al.*, 2007; Nikou and Economides, 2018). This finding is understandable as the development of microlearning is widely acknowledged as the result of the advancement of educational technology, including e-learning and mobile learning (Hug and Friesen, 2007).

Apart from *e-learning* and *mobile learning*, highly cited papers also focus on other topics, including *language teaching* (e.g. Edge *et al.*, 2011; Beaudin *et al.*, 2007), and *social media* (e.g. Sun *et al.*, 2015, 2018).

Themes in the knowledge base of microlearning

This finding used bibliographic coupling analysis to determine the most prevalent themes discussed in academic papers on microlearning from 2002 to 2021. Figure 6 highlights six clusters, each of which corresponds to a distinct theme of research in the field of microlearning. Table 3 depicts the number document and the most cited document of each cluster. The first cluster (red cluster) indicates the *Design and Evaluation of Mobile Learning* among the 15 articles with at least five citations. The second group of research (green cluster) examines *Microlearning Adaptation in MOOCs*. Meanwhile, the primary focus of the third cluster (blue cluster) is *Language Teaching and Learning*. The fourth cluster (yellow one) contains studies conducted on the *Workflow of a Microlearning System*. In this system, three key stages are defined: microlearning material generation, annotation of learning materials, and delivery of personalized learning materials (Lin *et al.*, 2020). The fifth cluster (the purple

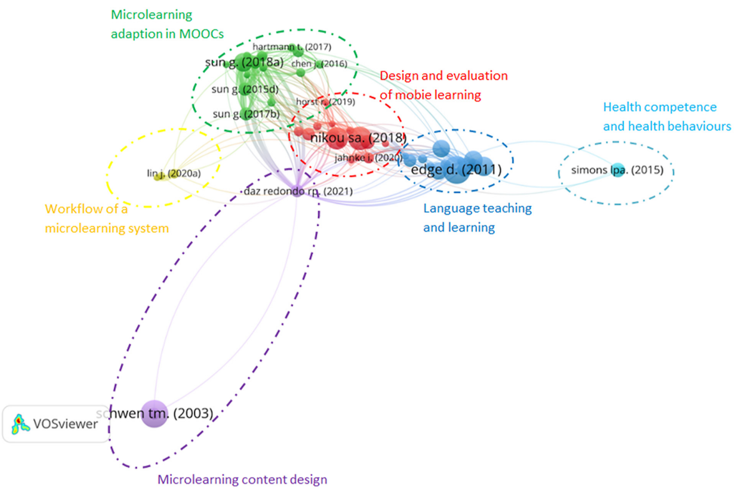

Figure 6.
Science mapping of bibliographic coupling analysis for documents of microlearning research (threshold 5 citations, display 50 documents)

Table 3.
Themes in the knowledge base of microlearning

No	Theme	Number of documents	The most cited document in the respective theme
1	Design and Evaluation of Mobile Learning	15	Nikou and Economides (2018)
2	Microlearning Adaptation in MOOCs	14	Sun *et al.* (2018)
3	Language Teaching and Learning	13	Edge *et al.* (2011)
4	Workflow of a Microlearning System	3	Lin *et al.* (2020)
5	Microlearning Content Design	3	Schwen and Hara (2003)
6	Health Competence and Health Behaviors	2	Simons *et al.* (2015)

cluster) focuses its research efforts on *Microlearning Content Design* (e.g. online design (Schwen and Hara, 2003), microlearning content on e-learning platforms (Díaz Redondo *et al.*, 2021)). Last but not least, the sixth theme (dark green cluster) is *Health Competence and Health Behaviors*. For example, a high-profile study of this cluster is the one of Simons *et al.* (2015) that designed a hybrid health support intervention system that includes a health microlearning quiz to support an aging workforce.

In general, documents in the knowledge base of microlearning mainly focus on three first themes which relate to how to design, adapt and evaluate microlearning on various online platforms (e.g. e-learning systems, MOOCs, and cloud systems). Furthermore, there are some emerging themes concerning the processing of a microlearning system, designing microlearning content and mapping health issues. These identified themes propose significant research directions for the future within the research community.

Table 4 displays the top ten sources with the highest number of microlearning publications, including information on their source types, subject areas, and total citations spanning the years 2002–2021. Regarding the type of source, seven out of the top 10 outlets are conferences, while only three are categorized as journals. It is worth noting that except three journals (i.e. *International Journal of Emerging Technologies in Learning, International*

ID	Source (type of source)	Scimago quartile in 2022	Subject area	TC	NP	Period
1	Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) (Conference)	Q3	Computer Science	165	14	2007–2020
2	ACM International Conference Proceeding Series (Conference)	N/A	Computer Science	32	7	2016–2021
3	Conference on Human Factors in Computing Systems – Proceedings (Conference) (discontinued in Scopus from 2020)	NA	Computer Science	186	6	2015–2021
4	Proceedings of the European Conference on E-Learning, ECEL Conference	NA	Educational technology	15	4	2011–2021
5	International Journal of Emerging Technologies in Learning Journal	Q1	Educational Technology	19	3	2017–2021
6	Advances in Intelligent Systems and Computing (Conference) (discontinued in Scopus from 2022)	NA	Computer Science	12	3	2017–2021
7	Journal of Physics: Conference Series (Conference)	Q4	Multidisciplinary	10	3	2013–2021
8	International Review of Research in Open and Distance Learning (Journal)	Q2	Educational Technology	62	2	2007–2019
9	Proceedings of the 19th International Conference on Human-Computer Interaction With Mobile Devices And Services, Mobilehci 2017 (Conference)	NA	Computer Science	44	2	2017–2017
10	Sustainability (Journal)	Q1	Multidisciplinary	25	2	2017–2021

Note(s): TC – Total Citations, NP – Number of Publications; Subject Area was assigned by the co-authors of this study; NA: not applicable; sources' information was referred from https://www.scopus.com/ at 10 a.m. November 23rd 2023

Table 4. Top 10 sources for microlearning research ranked by number of publications

Review of Research in Open and Distance Learning and *Sustainability*), the other sources are not among the top-quality journals or conferences. Indeed, certain sources have been even removed from the Scopus database, namely the *Conference on Human Factors in Computing Systems – Proceedings* and *Advances in Intelligent Systems and Computing*.

Regarding subject areas, the top 10 sources of microlearning research are predominantly centered on computer science, with five conferences, followed by educational technology (two journals and one conference). Notably, none of the top sources falls within the broader category of education. Once again, this finding underscores the prevalence of scholars in the field of information technology in microlearning research, as previously highlighted.

Source bibliographic coupling analysis

Figure 7 shows a network visualization map of bibliographic coupling analysis for outlets (i.e. journals, books, conferences) that published documents on microlearning. There are four clusters with four different colors corresponding to four scopes.

The red cluster is the largest, gathering seven outlets (International Journal of Knowledge and Learning; Journal of Physics: Conference Series; Advances in Intelligent Systems and Computing; Techtrends; IEEE Global Engineering Education Conference, Educon; Frontiers in Artificial Intelligence and Applications) and focusing on *education technology*.

The green cluster includes six *computer science*-related sources (International Journal of Engineering Education; Sustainability (Switzerland); Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST; Lecture Notes in Computer Science (including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); 2010 3rd International Symposium on

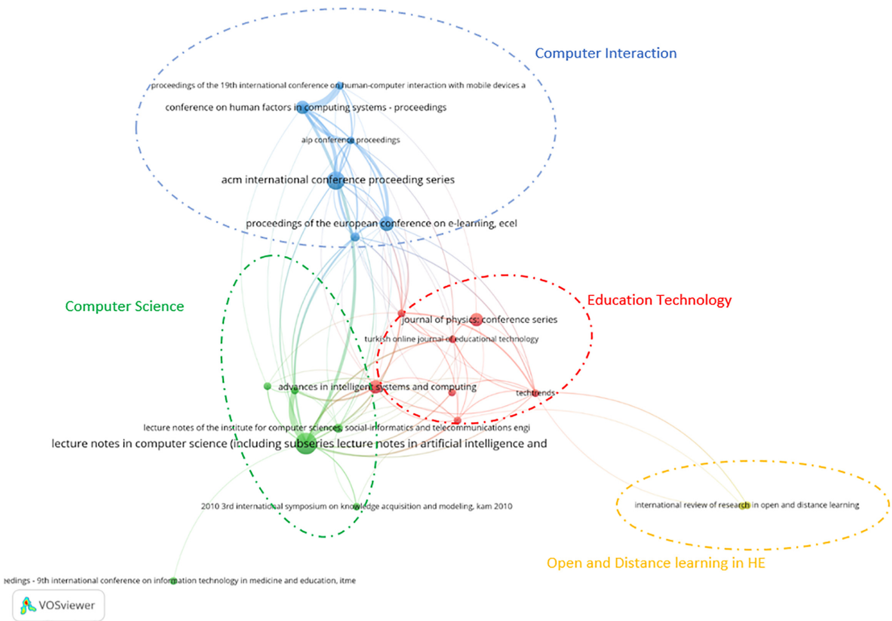

Figure 7.
Bibliographic coupling analysis science mapping for microlearning research sources (threshold 2 documents, 21 sources)

Knowledge Acquisition and Modeling, KAM 2010; Proceedings - 9th International Conference on Information Technology in Medicine and Education, ITME 2018.

The blue cluster comprises the same number of sources as the green cluster, concentrating on *computer interaction*. Journals and conferences included in this cluster are as follows: Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services; MOBILEHCI 2017; Conference on Human Factors in Computing Systems – Proceedings; AIP Conference Proceedings; ACM International Conference Proceeding Series; Proceedings of the European Conference on E-Learning, ECEL; and International Journal of Emerging Technologies in Learning.

Last but not least is *the orange cluster* with two sources focusing on *Open and Distance learning in higher education*, namely the Journal of Computing in Higher Education and International Review of Research in Open and Distance Learning.

Educational levels and their association with keywords in microlearning research

As mentioned earlier, apart from the available keywords provided by Scopus, we have created by ourselves another set of keywords according to the educational level of each document. Specifically, following the categorization of Vuong *et al.* (2020), we assign each document to one of the following educational levels: *Early Childhood Education (ECE), General Education (GE), Technical and Vocational Education and Training (TVET), Higher Education (HE), Lifelong Learning (LLL)* and *All Levels*. Among these levels, *All Levels* would be assigned to a document in which the object covers all levels of education, from *ECE* to *LLL* (e.g. Dhinakaran *et al.*, 2021; Yamina and Laskri, 2005).

As shown in Figure 8, *LLL* is the level at which we find the most documents on microlearning (111 documents, 37.37%). The second and third places, which are slightly behind *LLL* are *HE* with 90 documents (30.30%) and *All Levels* with 78 documents (26.26%). *LLL, HE* and *All Levels* contribute 279 documents, accounting for 93.94% of the total 297 microlearning documents. The three other educational levels only contribute the minor part

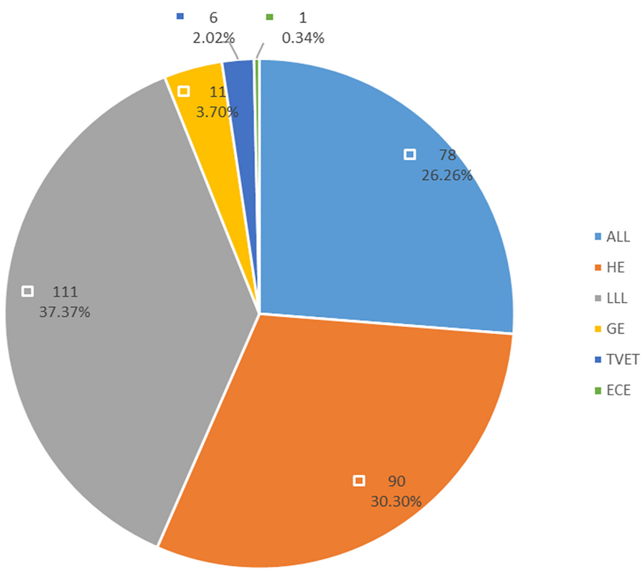

Figure 8. Number of microlearning documents based on educational levels

of the total publications, specifically *GE* (11 documents, 3.07%), *TVET* (6, 2.02%) and *ECE* (1, 0.34%). The leading role of *LLL* in microlearning is understandable as microlearning was initiated from corporate training (Redondo *et al.*, 2021), which is part of *LLL*. The finding of *HE* as the second most dominating educational level is explainable. *HE* is often regarded as the most innovative and autonomous subsector in education, which is always willing to adopt new initiatives and advancements like microlearning. On the other hand, a closer look at the list of *All levels* – microlearning documents such as Ali *et al.* (2021), Dessì *et al.* (2019), Gerbaudo *et al.* (2021) might help us to interpret their critical role. Apparently, these documents are conducted by scholars in computer science or information technology who intend to introduce tools or algorithms suitable for all levels rather than any specific level. This finding, again, highlights the important role of computer science and information technology scholars within the extant literature on microlearning studies.

On the one hand, many keywords (i.e. research topics) receive interest from different documents from different educational levels (see bold keywords in Table 5 and Appendix). For instance, the keywords *e-learning, gamification, mobile learning,* and *open education*

No	Educational levels	Shared keyword(s)
1	All levels – ECE – GE – HE – LLL – TVET	Microlearning
2	All levels – GE – HE – LLL – TVET	E-learning, gamification, mobile learning, open education resource
3	All levels – HE – LLL – TVET	Blended learning, MOOC
4	All levels – GE – HE – LLL	Collaborative learning
5	All levels – GE - LLL	Personalization
6	HE – LLL – TVET	Innovation, lifelong learning
7	All levels – HE – LLL	Big data, cloud computing, education, informal learning, language learning, online learning, social media, video, wait leaning
8	All levels – ECE	NA
9	All levels – TVET	NA
10	All levels – HE	Microlearning video, micro lecture, self-regulated learning, learning objects, social network, active learning, technology enhanced learning, learning cards, automated assessment
11	All levels – LLL	Web 2.0, question posing, engagement, instructional design, learning analytics, micro-content, assessment
12	All levels – GE	Microlearning course
13	TVET – GE	NA
14	ECE – TVET	NA
15	ECE – GE	NA
16	LLL – ECE	NA
17	LLL – TVET	Engineering education
18	LLL – GE	Personalization, just in time, mobile application, English language, unconscious learning
19	HE – LLL	Smartphone, LMS, user centered design, mobile learning, micro-credentials, personalized learning, information literacy, AI, innovation, non formal learning, chatbot, micro course, entrepreneurship, game based learning, programming languages, training
20	HE – ECE	NA
21	HE – GE	Motivation
22	HE – TVET	Microlearning resource

Note(s): NA: Not available

Table 5. Shared educational topics between educational levels

resource might be found in documents pertaining to *All levels, GE, HE, LLL* and *TVET*. Similarly, the keyword *collaborative learning* could be found in documents pertaining to *All levels, GE, HE,* and *LLL*. On the other hand, we also find several other keywords that receive interest from documents at a single educational level. For instance, we find three microlearning documents in *HE level* focusing specifically on *COVID-19*; two microlearning in *LLL level* focusing specifically on *Computer assisted language learning*. To visualize the different and indifferent interests of documents at various educational levels, we use Gephi software to build a 2-mode analysis, as shown in Figure 9.

Conclusion and implications

The overarching purpose of this study is to investigate the *state of art* of microlearning research indexed by Scopus between 2002 and 2021. Using bibliographic indicators, this study traces the growing pattern of microlearning research, unveils their document types, geographical distribution and co-author collaboration pattern by country, top authors and research groups, key outlets of publications and bibliographic coupling analysis.

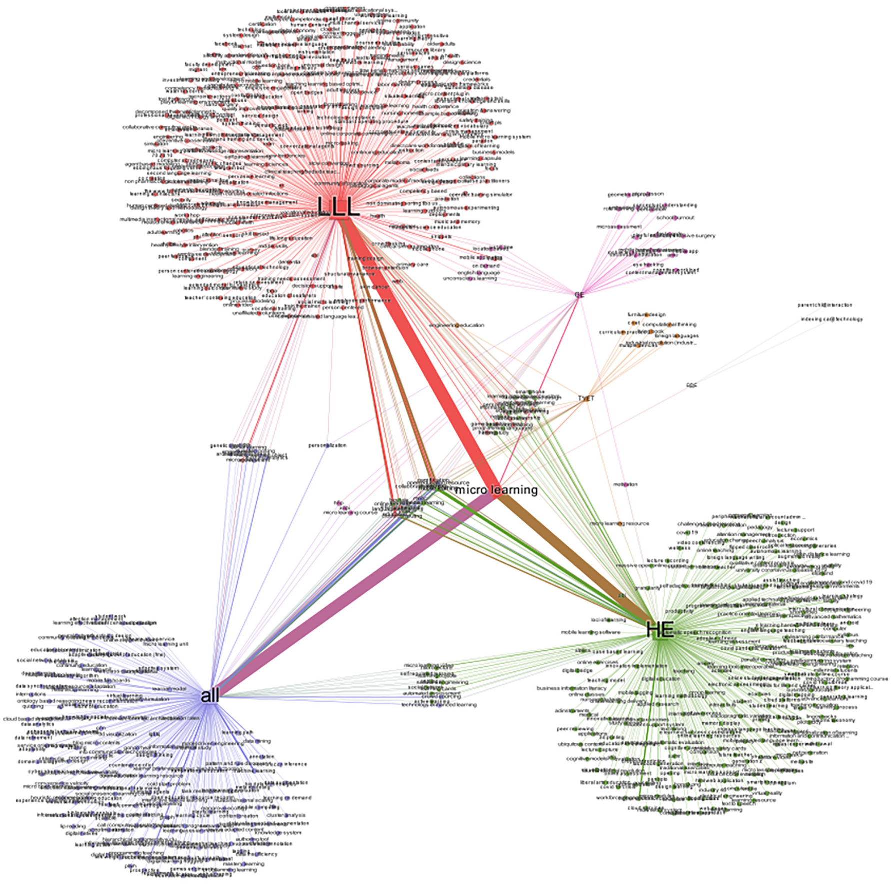

Figure 9. Science mapping of research topics according to different educational levels

Furthermore, this study also categorizes microlearning studies according to their educational levels along with respective keywords/topics.

This study provides several implications for stakeholders.

First, *educational researchers* who desire to conduct their research on microlearning may benefit from this review work. Specifically, key authors, sources of publications, sources of references, keywords identified in this study may serve as inputs for future microlearning researchers.

Specifically, there is a need for a deeper mutual understanding among scholars specializing in microlearning from the fields of educational technology and computer science/ information technology. The findings of this study suggest that these two groups of academics have operated in parallel without establishing close collaboration or cross-referencing. Furthermore, future scholars may consider delving into under-researched topics in microlearning, particularly at the levels of *TVET, GE*, and *ECE*, especially in fields beyond educational technology and computer science/information technology.

Second, as indicated by the above findings, the majority of sources in the existing microlearning literature are classified in the subject areas of educational technology or computer science. Therefore, we encourage *editorial boards of journals, book editors,* and *conference organizers* in other subject areas such as *LLL, HE, TVET, GE,* and *ECE* to consider incorporating microlearning and related factors, as represented in this study, into their future collections, themes, or special issues.

Third, *curriculum designers, lecturers* and *teachers* may consult best practices and empirical findings obtained from the bibliometric and science mapping analyses in this study in order to utilize in their daily professional activities such as curriculum, syllabus and content development, student instructing and mentoring.

Limitations

Like several other studies, this has limitations. First, in terms of research scope, this study concentrated solely on English language literature that was accessible on Scopus. This selection was made to ensure a detailed and focused analysis, but it may exclude relevant non-English language documents that could provide valuable perspectives on microlearning. Future studies incorporating non-English language sources could offer a more comprehensive understanding of microlearning in diverse educational settings. Second, due to the restricted quantity of words in a journal article, not all parts of bibliometric analysis, such as citation analysis and co-citation analysis, have been utilized in this work. Future research may incorporate these factors to investigate the field using various approaches. Third, despite the fact that, to the best of our knowledge, this study is one of the few bibliometric works that employs 2-mode analysis, its application has yet to be thoroughly investigated. Future research may employ a similar 2-mode analysis to offer insight into the extant microlearning literature. For example, future research may develop a new collection of keywords based on the subject of each document (e.g. computer science, foreign language) and combine this set of keywords with other sets, such as educational levels or Scopus-provided keywords, to generate a new 2-mode map. Lastly, the bibliometric analysis focuses mainly on bibliographic indicators while ignoring the contents of the corresponding papers. Future studies may combine bibliometric analysis with qualitative content analysis to gain insight into the current state of microlearning research.

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(The Appendix follows overleaf)

Appendix

ID	Educational level	Keyword (frequency)
1	ECE	microlearning (1) *Parent child interaction (1), indexing card technology (1)*
2	GE	microlearning (5), collaborative learning (1), e-learning (1), gamification (1), h5p (1), microlearning course (1), mobile learning (1), open education resource (1), personalization (1), xapi (1), English language (1), eye tracking (1), just in time (1), location-based (1), mobile (1), mobile application (1), motivation (1), on-demand (1), unconscious learning (1) *Micro lesson, rote learning (1), embedded librarianship (1), micro assessment (1), flashcards (1), playful environment (1), mobile app (1), mobile based assessment (1), mobile technology (1), cognitive workload (1) content management system (1), school burnout (1)*
3	TVET	microlearning (2), mobile learning (2), blended learning (1), e learning (1), gamification (1), MOOC (1), open education resource (1), innovation (1), lifelong learning (1), microlearning resource (1), engineering education (1) *Curriculum practice (1), multiple devices (1), living book (1), computational thinking (1), foreign languages (1), industrial revolution (1)*
4	HE	microlearning (47), mobile learning (14), e-learning (12), blended learning (5), education (5), MOOC (4), online learning (4), learning management system (4), gamification (3), micro lecture (3), smartphone (3), automated assessment (2), big data (2), cloud computing (2), collaborative learning (2), learning objects (2), artificial intelligence (2), case study (2), personalized learning (2), active learning (1), crowd sourcing (1), informal learning (1), language learning (1), learning cards (1), microlearning video (1), ontology (1), open education resource (1), self-regulated learning (1), social media (1), social network (1), software engineering (1), technology enhanced learning (1), video (1), wait learning (1), motivation (1), chatbot (1), cloud (1), English language learning (1), English language teaching (1), entrepreneurship (1), framework (1), future teacher (1), game based learning (1), information literacy (1), innovation (1), life long learning (1), micro course (1), micro credentials (1), microlearning resource (1), mobile microlearning (1), network (1), non formal learning (1), programming languages (1), training (1), user centered design (1) *COVID-19 (3), study abroad (2), Lecture support (1), student centered approach (1), self-adaptive learning (1), autonomous learning (1), augmented reality (1), English language learning (1), learning strategy (1), intercultural communication (1), learning progress (1), teaching innovation (1), readiness of student to take MOOC (1), learning performance (1), student support system (1), learning information service (1), online assessment (1), dropout prediction (1), further teacher (1)*
5	LLL	microlearning (59), mobile learning (10), e-learning (9), education (7), language learning (7), gamification (6), micro content (4), mobile (3), game based learning (3), lifelong learning (3), training (3), blended learning (2), collaborative learning (2), informal learning (2), online learning (2), social learning (2), artificial intelligence (2), micro course (2), micro credentials (2), non-formal learning (2), architecture (1), assessment (1), big data (1), cloud computing (1), engagement (1), genetic algorithm (1), instructional design (1), learning analytics (1), microlearning object (1), MOOC (1), open education resource (1), personalization (1), question posing (1), social media (1), video (1), wait learning (1), web 20 (1), English language (1), just in time (1), location based (1), mobile application (1), on demand (1), unconscious learning (1), case study (1), chatbot (1), cloud (1), entrepreneurship (1), framework (1), information literacy (1), innovation (1), learning management system (1), mobile microlearning (1), network (1), personalized learning (1), programming languages (1), smartphone (1), user centered design (1), engineering education (1) *Computer assisted language learning (2), adult learning (2), online corporate of practice (2), Employee performance (1), user experience (1), social microlearning (1), teachers' continuing education (1), micro platform (1), ubiquitous learning (1), robotics (1), non standard workers (1), corporate education system (1), self-paced learning (1), public libraries (1), continuing education (1), operator training simulator (1), safety training (1), example based training (1), playful learning environment (1), security as a service (1), certification (1), employee competency (1), competency development (1), learning theory (1), self-management (1), labor market (1), interactive learning environment (1)*

(*continued*)

Table A1. Specific topics of educational levels

ID	Educational level	Keyword (frequency)
6	All levels	microlearning (55), mobile learning (10), open education resource (7), e learning (6), MOOC (6), gamification (4), learning analytics (4), blended learning (3), crowd sourcing (3), big data (2), micro content (2), personalization (2), social learning (2), social media (2), technology enhanced learning (2), active learning (1), architecture (1), assessment (1), automated assessment (1), cloud computing (1), collaborative learning (1), education (1), engagement (1), genetic algorithm (1), h5p (1), informal learning (1), instructional design (1), language learning (1), learning cards (1), learning objects (1), microlearning course (1), microlearning object (1), microlearning video (1), micro lecture (1), online learning (1), ontology (1), playful learning (1), programming learning (1), programming teaching (1), question posing (1), self-regulated learning (1), social network (1), software engineering (1), video (1), wait learning (1), web 20 (1), xapi (1) *Adaptive system (3), learning path (3), educational data mining (3), deep learning (2), Online support system (1), virtual learning (1), learner model (1), learner profile (1), content packaging (1), big data technologies (1), learning cycle (1), ICT (1), micro open learning (1), blended schooling (1), content creation (1), digital learning environment (1), game engineering (1), video classification (1), information filtering (1), student-centered learning (1)*

Note(s): Keywords *in italic* are found in only one respective education level; keywords in underline are found in at least two education levels

Table A1.

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