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A Scientometric Study of Digital Literacy, ICT Literacy, Information Literacy, and Media Literacy

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Abstract

Purpose: Digital literacy and related fields have received interests from scholars and practitioners for more than 20 years; nonetheless, academic communities need to systematically review how the fields have developed. This study aims to investigate the research trends of digital literacy and related concepts since the year of 2000, especially in education.

Design/methodology/approach: The current study analyzes keywords, co-authorship, and cited publications in digital literacy through the scientometric method. The journal articles have been retrieved from the WoS (Web of Science) using four keywords: "Digital literacy," "ICT literacy," "information literacy," and "media literacy." Further, keywords, publications, and co-authorship are examined and further classified into clusters for more in-depth investigation.

Findings: Digital literacy is a multidisciplinary field that widely embraces literacy, ICT, the Internet, computer skill proficiency, science, nursing, health, and language education. The participants, or study subjects, in digital literacy research range from primary students to professionals, and the co-authorship clusters are distinctive by countries in America and Europe.

Research limitations: This paper analyzes one fixed chunk of a dataset obtained by searching for all four keywords at once. Further studies will retrieve the data from diverse disciplines and will trace the change of the leading research themes by time spans.

Practical implications: To shed light on the findings, using customized digital literacy curriculums and technology is critical for learners at different ages to nurture digital literacy according to their learning aims. They need to cultivate their understanding of the social impact of exploiting technology and computational thinking. To increase the originality of

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digital literacy-related studies, researchers from different countries and cultures may collaborate to investigate a broader range of digital literacy environments.

Originality/value: The present study reviews research trends in digital literacy and related areas by performing a scientometric study to analyze multidimensional aspects in the fields, including keywords, journal titles, co-authorship, and cited publications.

Keywords Digital literacy; ICT literacy, Information literacy; Media literacy; Scientometrics

1 Introduction

With the emergence of new digital technology, acquiring and using necessary information has become a necessary skill to improve. Digital literacy was first introduced by Paul Gilster (1997), which is "a framework for integrating various other literacies and skill-sets, though it does not need to encompass them all" (Bawden, 2008). As stated in the special issue on data science in the *Science* (Science staff, 2011), how to make the best use of raw materials for analytics and visualization has become an essential part of digital literacy. Digital literacy is the recognition of the information that learners obtain through a networked medium, in which they are exposed to network computers and experience the cognitive information processing that is similar to reading newspapers and watching the television. It is the skill to exploit the technology for reading, writing, and living in the digital age (Bawden, 2008). According to Martin and Grudziecki (2006), digital literacy has three levels: digital competence in level 1, digital usage in level 2, and digital transformation in level 3. Digital competence includes both lower and higher order thinking skills, from basic skills to analytical skills. Digital usage relates to the application of digital competency to domain-specific areas, and digital transformation occurs when digital usage transforms the domain-specific areas using creativity. These three levels in digital literacy are in line with Gilster's (1997) research, in which learners filter out unrefined information obtained from the Internet and then evaluate and transform the information into knowledge.

Researchers have discussed that digital literacy is interchangeable with other related terminologies. Information literacy, which received significant attention in higher education in the 1990s, and media literacy are regarded as similar to digital literacy. Other relevant concepts include computer literacy, primarily used in the 1980s, in addition to ICT literacy, network literacy, and e-literacy (Bawden, 2008; Koltay, 2011). Of them, media literacy is considered a skill to use and evaluate the information that is obtained from mass media. Along with media literacy, computer literacy and e-literacy are skill-based literacies that have been developed with the emerging technology, which helped propose the need for improving information

literacy that assesses and uses the content of information (Bawden, 2001; Martin & Grudziecki, 2006). Moreover, using the plural form, "digital literacies," was emphasized by Lankshear and Knobel (2008) to discuss diverse policies related to digital literacy. Digital literacies are seen from a wide range of sociocultural perspectives (Gee, 1996; Lankshear, 1987; Street, 1984) as "new literacies" similarly does (Knobel & Lankshear, 2006), enlarging the comprehensive perspectives toward the digital literacy with its educational significance.

Notwithstanding the diversity of similar concepts (Bawden, 2008), digital literacy has been discussed across the education and other sectors in practice. For example, Educational Testing Service (ETS) held an international panel to discuss the relationship between digital literacy and Information and Communication Technology (ICT), an emerging concept at that time, and the influence of the growth of the two areas (International ICT Literacy Panel, 2002). From a public policy perspective, the government of South Korea has nurtured the public's digital literacy skills and established a national guideline to improve primary and secondary students' digital literacy skills (Ministry of Education & Human Resources Development, 2005). Despite the effort, South Korea's digital literacy education is inconsistent with its' initial policy direction (Lee et al., 2019) as the country ranked highly in digital literacy levels (Dwyer & Hutchinson, 2019; European Commission, 2014) although students' awareness and interest in digital device utilization ranked at the bottom of the PISA 2015 results (Kim et al., 2017). It is time to identify over 20-year development of digital literacy and to devise educational programs and policies according to digital literacy levels of learners. A systematic analysis of previous studies on digital literacy and related concepts is necessary to review how the areas have developed and discussed so far and suggest ways to improve the fields in practice.

This study aims to investigate the research trends of digital literacy and related concepts in education fields. This paper will adopt scientometrics, i.e. a quantitative investigation of sciences, to mine big-sized bibliographic data and analyze the research patterns and impact reflected in research articles. It will further illustrate intellectual structures and development of the research on digital literacy in education. This paper will address the following questions: a) What topics have been discussed in digital literacy since the year 2000?; b) How have digital literacy researchers collaborated and on which topics?; and c) What publications and journals have been cited frequently and what they have discussed? The adopted methods and tools will be described, and the results will be elaborated along with the implication to improve future research in the fields.

2 Methodology

2.1 Data collection

The data for this study was downloaded from the WoS. The articles were retrieved by using the Boolean search method with the four keywords with "OR" between them: "digital literacy," "ICT literacy," "information literacy," "media literacy." These keywords were selected based on previous studies (Ahn, 2017; Koltay, 2011). More specifically, "digital literacy," "information literacy," and "media literacy" were selected since they were prevalently used keywords, according to Koltay (2011). "ICT literacy" was additionally included as it was adopted in the Korean national guideline (Ahn, 2017). Other related keywords (e.g. e-literacy and computer literacy) may be counted; however, we only focus on the four selected keywords in the present study since they are prevailing concepts. The publication period of the downloaded articles ranged from the year 2000 to the date the data was downloaded, November 13th, 2018. A total of 3,424 articles were retrieved. Of them, journal articles in education-related sections (education educational research, education scientific discipline, psychology educational, and education special) were chosen for the analysis in this research. After the selection process, the final dataset had 728 journal articles with a total of 22,570 references.

2.2 Data analysis

Scientometrics is a scientific method to quantitatively measure research influence (Garfield, 2006). The present study retrieved journal articles and investigated the articles as well as the publications cited in them in terms of keyword, co-authorship, and cluster.

Three different types of keywords (author keywords, topic keywords, and co-occurring keywords) were examined. First, author keywords were determined by the authors of the articles. Second, topic keywords were suggested by the WoS to illustrate the research topics of the articles reviewed. That is, while author keywords are the terms that the authors of the articles indicate commonly below the abstracts of the articles, topic keywords are the terms that the WoS determines by using an algorithm to explore the reference and bibliographic information (Clarivate, 2020). We included both author and topic keywords in our data analysis due to the different coverage of each. Third, keywords that co-occur in the same articles were analyzed to discover research themes and clusters.

VOSviewer version 1.6.9 (CWTS Leiden, 2018) was used to analyze the co-occurring keywords through natural language processing algorithms. For the cluster analysis of the co-occurring keywords, the unified approach of mapping and clustering methods was adopted to categorize the clusters based on similar content

and topics and illustrate the weighted cluster network according to the strength of the association between the keywords (Waltman, van Eck, & Noyons, 2010). The keywords that have links with other keywords (co-occurrence) and the clusters of those keywords will be underlined in this paper by the strength of linkage, which shows the frequency of the co-occurrences. Also, a list of the individual keywords that have the most links with other keywords will be presented (van Eck & Waltman, 2014).

VOSviewer version 1.6.9 (CWTS Leiden, 2018) was also utilized to figure out the co-authors and their clusters based on the information about author name, organization, and country/region (van Eck & Waltman, 2020; Waltman, van Eck, & Noyons, 2010). Each cluster had authors who produced at least one research article and collaborated multiple times (Palmblad & van Eck, 2018).

Co-citation analysis (Marshakova, 1973; Small, 1973) was conducted to investigate the structures and research themes of the co-cited publications. Using CiteSpace version 5.1.R2 (Chen, 2017), the clusters' themes were named based on the keywords designated by the authors of the collected articles and the WoS. The size of each cluster was proportional to the number of co-authored publications. The year of the creation of each cluster was when the first co-citation occurred.

3 Results

3.1 Journals

"Comunicar" (108 times) was the journal where research articles on digital literacy were published most frequently (Table 1). This journal published over 1,770 articles on educommunication (education and communication) and ICT over the past 25 years (Comunicar, 2018). Other journals on the list were related to literacy (e.g. "Journal of Adolescent and Adult Literacy," "Literacy") and information, media, computers, and technology (e.g. "Computers and Education," "Learning Media and Technology"). Journals that converse about science, nursing, health, and English education were also listed.

3.2 Keywords

The frequent author keywords covered literacy, information and technology, pedagogy, student behavior, attitude, and beliefs (Table 2). "Media literacy" was the most frequent, and its plural form, "media literacies," was also listed. Other keywords, such as "children," "higher education," and "teacher education," narrated educational levels and age.

The most frequent topic keyword was "education" (Table 3). Some keywords were related to subjects at various ages (e.g. "students," "children," "adolescents")

Table 1. Journals in which articles on digital literacy were published the most.

Rank	Journals	Occurrence
1	Comunicar	108
2	Computers and Education	59
3	Journal of Adolescent and Adult Literacy	38
4	Journal of Chemical Education	27
5	Learning Media and Technology	25
6	Literacy	17
7	British Journal of Educational Technology	14
	Educational Technology and Society	
9	Nurse Education Today	12
10	English Teaching: Practice and Critique	11
	Reading Teacher	
12	Journal of Computer Assisted Learning	10
	Language and Education	
14	Internet and Higher Education	8
	Technology, Pedagogy, and Education	
16	Asia-Pacific Education Researcher	7
	Cultura y Educación	
	ETR&D-Educational Technology Research and Development	
	Eurasia Journal of Mathematics Science and Technology Education	
	Health Education Research	
	Journal of Literacy Research	
	Journal of School Health	

Table 2. Frequent author keywords.

Rank	Author Keywords	Occurrence
1	Media literacy	109
2	Digital literacy	90
3	Information literacy	66
4	Digital	39
5	Media education	30
6	Media	27
7	ICT	21
8	Literacy	20
9	ICT literacy	18
	Media literacies	
	New literacies	
12	Education	14
	Information	
	Pedagogy	
	Technology	
16	Internet	13
17	Children	12
	Higher education	
	Teacher education	
20	Multimodality	11

and information and technology (e.g. "technology," "Internet," "Web," "online"). Other research topics of the retrieved articles incorporated teaching and learning, curriculum, and learners' attitude, belief, and behavior.

Table 3. Frequent topic keywords.

Rank	Topic Keywords	Occurrence
1	Education	88
2	Students	59
3	Technology	58
4	Literacy	44
5	Skills	36
6	Information literacy	35
7	Knowledge	30
8	Internet	26
9	Curriculum	25
10	Information	24
11	Web	23
12	Children	22
13	Science	21
14	Attitudes	19
	Media literacy	
	Model	
	Online	
18	Adolescents	18
19	Behavior	16
	Beliefs	
	Instruction	

The co-occurring keywords included "information literacy," "education," "digital literacy," "media literacy," and "media literacies" (Table 4). Other co-occurring keywords were related to pedagogy (e.g. "instructional strategies," "methods"), learners (e.g. "students," "adolescence," "university students," "early adolescence"), Internet and technology (e.g. "digital," "specific media"), and culture and literacy (e.g. "film," "music," and "popular culture").

The co-occurring keywords were classified into seven clusters (Figure 1). Cluster 1 had the most keywords (78 keywords), while cluster 7 had the least keywords (12 keywords). More specifically, cluster 1 had keywords about digital literacy, learners' attitudes, and learning contexts. Cluster 2 illustrated media and technology. It also talked about learners' age group, learning strategies, teacher education, and health and social issues. Cluster 3 covered strategies for teaching and learning, research methods and fields, and learners' age group. Cluster 4 discussed more diverse learner groups, including "university students" along with "writing," "motivation," "engagement," "domain knowledge," and "instructional strategies." Cluster 5 had domain-specific terms that were mentioned with learners' age groups

and learning strategies. For instance, "chemical information," "chemoinformatics," and "organic chemistry" appeared with learner groups and learning strategic terms. Next, cluster 6 discussed culture and language, along with "multiliteracies," "multimodality," "policy," and "reading." Lastly, cluster 7 covered "assessment," "credibility," "epistemological beliefs," "personal epistemology," "prior knowledge," and "comprehension" (see Appendix for the whole list of the co-occurring keywords). To sum, the range of research topics in digital literacy has been expanded, which embraces assessment, credibility, learners' attitudes, and media literacy education. Learners, or study subjects, included from early adolescents to adults and professional groups, along with further clarifications by gender and identity.

Table 4. Keywords of co-occurrence.

Rank	Keywords	Co-occurrence
1	Information literacy	660
2	Education	468
3	Internet	447
4	Digital literacy	437
5	Media literacy	435
6	Technology	390
7	Media literacies	361
8	Digital	331
9	Students	326
10	Adolescence	297
11	Literacy	295
12	University students	274
13	Instructional strategies	263
14	Methods	246
15	Film	242
16	Early adolescence	234
17	Strategies	231
18	Music	229
19	Specific media	227
20	Popular culture	217

3.3 Co-authorship

The results revealed that 1,453 authors collaborated with other authors to write research articles. Table 5 shows the top co-authors by the frequency of co-authorship. Consequently, Valcke, M., Claro, M., and San Martin, E., respectively, produced research articles with other researchers the most. Valcke, M. studied innovation in higher education and the integrated use of ICT at Ghent University in Belgium (Ghent University, 2018). Claro, M. and San Martin, E. researched digital technology and education (Pontificia Universidad Católica de Chile, 2018).

The network of co-authors consists of 563 clusters. Of the total clusters, the top 10 clusters consisted of the most co-authors, respectively, and are presented in the current paper (Figure 2). In cluster 1, Han and Schuurmans-Stekhoven (2017)

Research Paper

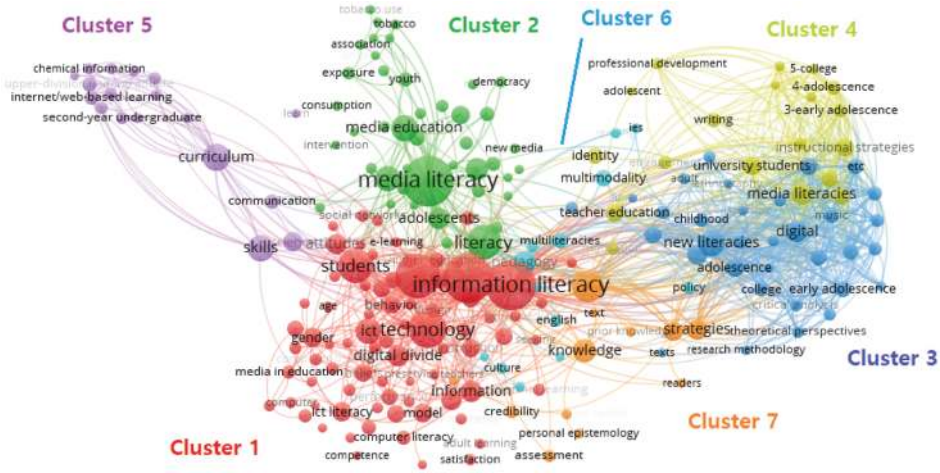

Figure 1. Clusters of co-occurring keywords.

Table 5. Authors who produced research articles with other authors.

Rank	Co-authors	Frequency
1	Valcke, M. Claro, M. San Martin, E	16
4	Kiili, C. Leu, D. J.	14
6	Clark, A. Jara, I. Preiss, D. D. Valenzuela, S.	13
10	Primack, B. A. Chen, C. H.	12
12	Lin, T. B. Dagenais, D. Toohey, K. Chang, K. E. Chang, T. Y. Hu, K. W. Huang, C. J. Huang, K. L. Huang, T. H. Liao, J. J. Liu, M. C. Luo, Y. C. Shen, H. Y. Sung, Y. T. Leppanen, P. H. T.	11

examined Asian students' research literacy in higher education in Australia, using information and technology. Other co-author groups studied individual- and school-level variables which influenced South Korean primary students' ICT literacy (Kim, Kil, & Shin, 2014) and South Korean secondary school students' ICT literacy skills (Kim & Lee, 2013).

Next, in cluster 2, research on students' use of iPad applications to obtain scientific knowledge and ask inquiries when they visited a science museum (Marty et al., 2013). Cluster 3 had a study on Brazilian students' online use and their home background (Cabello-hutt, Cabello, & Claro, 2017). On the one hand, many of the authors found in cluster 4 worked together for Taiwanese primary school students' ICT literacy improvement and learning-assistance tool (Huang et al., 2010). In cluster 5, a study on the perception of students at 20 secondary schools in Belgium for their use of video games in class (Bourgonjon et al., 2010). In cluster 6, literacy studies in health were found—the influence of anti-smoking media literacy curriculum for 1,170 9th Grade American students' media literacy and smoking (Primack et al., 2014) and online anti-smoking program for 9th Grade students (Phelps-Tschang et al., 2015; Primack et al., 2009). Cluster 7 had research on students' ICT literacy assessment instrument (Siddiq, Gochyyev, & Wilson, 2017), use of data for sustainable improvement of learning (Scalise & Wilson, 2011), and relationships between self-efficacy, ICT use, socio-economic background of about 60,000 students in 21 different countries located in Europe, Asia, and South America (Hatlevik et al., 2018). In cluster 9, Prieto et al. (2016) introduced four research projects on the socio-cultural approach to mobile learning. Another relevant article (Garcia et al., 2015) discussed the critical literacy of secondary school students, teachers, professors, and graduate students who were involved in the community for improving education in urban areas of the United States. Lastly, in cluster 10, the influence of emotional design in multimedia learning on understanding and achievement was studied (Plass et al., 2014). The authors of this study collaborated with other researchers to investigate how playing digital games accompanied by physical activity influences children's reading skills between the ages of five and seven (Homer et al., 2014).

The co-authorship clusters showed how authors from certain countries collaborated (Figure 2). For example, cluster 1 was constructed by the co-authors from South Korea and Australia. Most researchers in cluster 4 were from Chinese taiwan. Other large clusters were shaped by American authors who worked with researchers from South America (e.g. Chile) and Europe (e.g. Norway, Germany, Finland, Belgium).

Research Paper

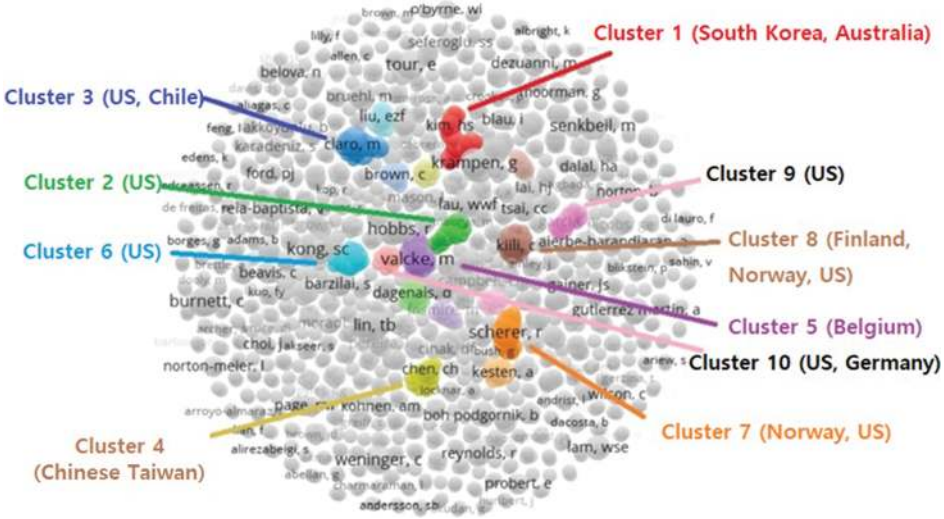

Figure 2. Clusters of co-authorships.

3.4 Publications

Table 6 shows the frequently cited journal articles, books, and reports. The books and chapters on the list discussed cultural competencies and social skills that are needed to exploit digital technology. Specific topics were sociocultural perspectives during the process of reading, writing, and deriving meaning (Jenkins, 2006a; Knobel & Lankshear, 2006), the change in media education (Buckingham, 2003), research methodology and literacy (Coiro et al., 2008), and literacy in New Media Age and Digital Age (Binkley et al., 2012; Fraillon et al., 2014; Kress, 2003). Of them, the most cited publication was *Confronting the Challenges of Participatory Culture* (Jenkins, 2006a, 2009), which was published as an occasional paper in 2006 and as a book in 2009.

Of the list, the frequently cited journal articles presented the results of experimental studies (Tables 6 & 7). Primarily, there were studies on learning outcomes and skills for digital literacy of the digital native who grew with using digital technology in their daily life (Bennett, 2008; Claro et al., 2012; Greene, Yu, & Copeland, 2014; Hargittai, 2010; Ng, 2012). Other studies presented educational programs for students in chemistry to master their literature searching skills (Gawalt & Adams, 2011; Locknar et al., 2012) and definition of media literacy, information literacy, and digital literacy (Koltay, 2011).

Table 6. Frequently cited publications.

Rank	References	Citation
1	Jenkins, H. (2009). *Confronting the challenges of participatory culture.* Cambridge, Massachusetts: The MIT Press.	19
2	Jenkins, H. (2006a). *Confronting the challenges of participatory culture.* Cambridge, Massachusetts: The MIT Press.	17
3	Knobel, M., & Lankshear, C. (2006). *A new literacies sampler*. NY: Peter Lang.	14
4	Ng, W. (2012). Can we teach digital natives digital literacy?. *Computers & Education, 59*(3), 1065–1078.	13
5	Jenkins, H. (2006b). *Convergence culture: Where old and new media collide.* New York, NY: NYU Press. Fraillon, J., Schulz, W., & Ainley, J. (2013). *International computer and information literacy study.* Amsterdam, the Netherlands: IEA Gawalt, E., & Adams, B. (2011). A chemical information literacy program for first-year students. *Journal of Chemical Education, 88*(4), 402–407.	11
8	Hargittai, E. (2010). Digital na(t)ives? Variation in Internet skills and uses among members of the net generation. *Sociological Inquiry, 80*(1), 92–113. Buckingham, D. (2003). *Media education: Literacy, learning and contemporary culture.* Cambridge, UK: Polity. Bennett, S. (2008). The 'digital natives' debate: A critical review of the evidence. *British Journal of Educational Technology, 39*(5), 775–786. Coiro, J.. Knobel, M., Lankshear, C., & Leu, D. (2008). *Handbook of research on new literacies.* New York, NY: Taylor & Francis Group. Kress, G. (2003). *Literacy in the new media age*. New York, NY: Routledge.	10
13	Hobbs, R. (2010). *Digital and media literacy: A plan of action*. Washington, D. C.: The Aspen Institute. Binkley, R., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In P., Griffin, B., McGaw, & E., Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 17–66). Dordrecht, Germany: Springer Science+Business Media B. V.	9
15	Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Gebhardt, E. (2013). Preparing for life in a digital age. DOI 10.1007/978-3-319-14222-7 Locknar, A., Mitchell, R., Rankin, J., & Sadoway, D. (2012). Integration of information literacy components into a large first-year lecture-based chemistry course. *Journal of Chemical Education, 89*, 487–491. Ferres, J., & Piscitelli, A. (2012). Media competence. Articulated proposal of dimensions and indicators. *Comunicar, 19*(38), 75–81. Ito, M., Baumer, S., Bittani, M., Boyd, D., Cody, R., Herr-Stephenson, B....., Tripp, L. (2010). *Hang out, messing around, and geeking out: Kids living and learning with new media*. Cambridge, Mass.: The MIT Press. Claro, M., Preiss, D., Martin, E., Jara, I., Hinostroza, J., Valenzuela, S....., Nussbaum, M. (2012). Assessment of 21st century ICT skills in Chile: Test design and results from high school level students. *Computers & Education, 59*(3), 1042–1053. Greene, J. A., Yu, S. B., & Copeland, D. Z. (2014). Measuring critical components of digital literacy and their relationships with learning. *Computers & Education, 76*, 55–69. Koltay, T. (2011). The media and the literacies: media literacy, information literacy, digital literacy. *Media, Culture & Society, 33*(2), 211–221.	8

Table 7. Frequently cited journal articles and main findings.

Articles	Topic	Participant	Major finding
Ng (2012)	Digital natives' use of new technology and digital literacy	Undergraduate students (pre-service teachers who are yet to become teachers)	• Undergraduate students learned the new technology easily and used it in a meaningful way for learning.
Gawalt and Adams (2011)	Chemical information literacy program	Undergraduate students taking chemistry course and instructors	• Chemical information literacy program was useful for instructors and students to search and read literature.
Hargittai (2010)	Internet users' skills and diversity	Undergraduate students	• Socioeconomic status was a critical predictor of undergraduate students' Internet use in their daily life.
Bennett (2008)	Debate on digital native	Literature on digital native	• Renovated education should be provided to meet the needs of digital natives
Locknar et al. (2012)	Discovering Scientific Information Program (DSIP)	Undergraduate students taking chemistry course	• Using DSIP improved students' library research skills.
Ferres and Piscitelli (2012)	Criteria for media education or media literacy and indicators for new media competence	-	• Media education along with critical thinking and aesthetic thinking was suggested. • Convergence of technological revolution and neurobiological revolution was proposed.
Claro et al. (2012)	Chilean secondary school students' ICT skills	Chilean secondary school students	• Students tended to utilize ICT skills as information consumers rather than information producers. • Students' socioeconomic aspects, daily use, accessibility, and confidence in using ICT were related to their academic performance.
Greene et al. (2014)	Self-regulated learning (SRL), Epistemic Cognition (EC), and academic performance	Undergraduate students	• Internet-based learning enhanced students' understanding. • SRL and EC were related to digital learning outcomes.
Koltay (2011)	Similarities and differences between media literacy, information literacy, and digital literacy	-	• Media literacy, information literacy, and digital literacy were compared in terms of definition and features.

The co-cited publications were classified into eight clusters that described overarching topics (Table 8). The cluster numbers shown in Table 8 were designated by the analysis tool in accordance with the size of the cluster in ascending order. For example, cluster 0 has the most co-cited publications. That is, the biggest cluster was "digital literacy." Other clusters included "ICT literacy," "epistemic perspective," "exploratory study," "performance test," "school-performance feedback use," and

"online forum." Meanwhile, the visualized network of the clusters showed that the cluster, "integrating chemical information instruction," was remote from the other clusters (Figure 3). This finding indicates that publications in "integrating chemical information instruction" were co-cited within the cluster, while publications in the other clusters were likely to be co-cited across the clusters.

A zoomed-in network of the clusters showed the co-cited publications between the clusters more precisely. Cluster color demonstrated a year when first co-citation occurred in a cluster (Chen, 2006), which means the time when the cluster was created. Yellow-green had its first co-citation in 2005, while co-citation occurred in more recent years as a cluster's color gets closer to red-orange. In terms of the two clusters with the same topic, "ICT literacy," one was created in 2010, while the other one was in 2015 and is located between "Neil Postmans view" and "digital literacy" clusters in the network. "Digital literacy" clusters were adjacent to "performance," and "exploratory study" and were closely related to "epistemic perspective" among the co-cited publications.

Table 8. Clusters of co-cited publications.

Cluster	Cluster topic (Co-cited publications, mean year of co-citations)	Major co-cited publications
0	Digital literacy (55, 2007)	• Jenkins, H. (2006b). *Convergence culture: Where old and new media collide.* New York, NY: NYU Press. • Bennett, S. (2008). The 'digital natives' debate: A critical review of the evidence. *British Journal of Educational Technology, 39*(5), 775–786. • Coiro, J.. Knobel, M., Lankshear, C., & Leu, D. (2008). *Handbook of research on new literacies*. New York, NY: Taylor & Francis Group. • Lankshear, C., & Knobel, M. (2006). *New literacies. Everyday practices and classroom learning* (2nd ed.). New York, NY: Open University Press. • Kress, G. (2003). *Literacy in the new media age*. New York, NY: Routledge.
1	ICT literacy (42, 2012)	• Fraillon, J., Schulz, W., & Ainley, J. (2013). *International computer and information literacy study.* Amsterdam, the Netherlands: IEA • Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Gebhardt, E. (2013). Preparing for life in a digital age. DOI 10.1007/978-3-319-14222-7 • Binkley, R., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In P., Griffin, B., McGaw, & E., Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 17–66). Dordrecht, Germany: Springer Science+Business Media B.V.
2	Epistemic perspective (37, 2010)	• Barzilai, S., & Zohar, A. (2012). Epistemic thinking in action: Evaluating and integrating online sources. *Cognition and Instruction, 30*(1), 39–85.

Cluster	Cluster topic (Co-cited publications, mean year of co-citations)	Major co-cited publications
3	Exploratory study (32, 2013)	• Ng, W. (2012). Can we teach digital natives digital literacy?. *Computers & Education, 59*(3), 1065–1078. • Greene, J. A., Yu, S. B., & Copeland, D. Z. (2014). Measuring critical components of digital literacy and their relationships with learning. *Computers & Education, 76*, 55–69.
4	Performance test (25, 2008)	• Hargittai, E. (2010). Digital na(t)ives? Variation in Internet skills and uses among members of the net generation. *Sociological Inquiry, 80*(1), 92–113.
5	Integrating chemical information instruction (24, 2012)	• Gawalt, E., & Adams, B. (2011). A chemical information literacy program for first-year students. *Journal of Chemical Education, 88*(4), 402–407. • Locknar, A., Mitchell, R., Rankin, J., & Sadoway, D. (2012). Integration of information literacy components into a large first-year lecture-based chemistry course. *Journal of Chemical Education, 89*, 487–491.
6	Cigarette smoking (19, 2005)	• Primack et al. (2006). Association of cigarette smoking and media literacyabout smoking among adolescents. *Journal of Adolescent Health, 39*(4), 465–472.
7	ICT literacy (18, 2006)	• Ferres, J., & Piscitelli, A. (2012). Media competence. Articulated proposal of dimensions and indicators. *Comunicar, 19*(38), 75–81.
8	Neil Postmans view (16, 2010)	• Jenkins, H. (2009). *Confronting the challenges of participatory culture*. Cambridge, Massachusetts: The MIT Press.
9	School-performance feedback use (15, 2006)	• Schildkamp, K., Visscher, A., & Luyten, H. (2009). The effects of the use of a school self-evaluation instrument. *School Effectiveness and School Improvement, 20*(1), 69–88.
10	Online forum (12, 2009)	• Ito, M., Baumer, S., Bittani, M., Boyd, D., Cody, R., Herr-Stephenson, B....., Tripp, L. (2010). *Hang out, messing around, and geeking out: Kids living and learning with new media*. Cambridge, Mass.: The MIT Press.
14	Professional practice (9, 2007)	• Hermans, R., Tondeur, J., van Braak, J., & Valcke, M. (2008). The impact of primary school teachers' educational beliefs on the classroom use of computers. *Computers & Education, 51*(4), 1499–1509.
17	Regarding media (6, 2006)	• Livingstone, S. (2004). Media literacy and the challenges of new information and communication technologies. *Communication Review, 7*(1), 3–14.

4 Discussion and conclusion

This paper explored a dataset of journal articles indexed in the WoS to examine research trends in digital literacy through scientometrics. Consequently, digital literacy was studied in various fields, such as media and information, science, nursing, health, and language education. The research keywords were related to literacy, ICT, curriculum, and pedagogy as well as learners' attitude, belief, and

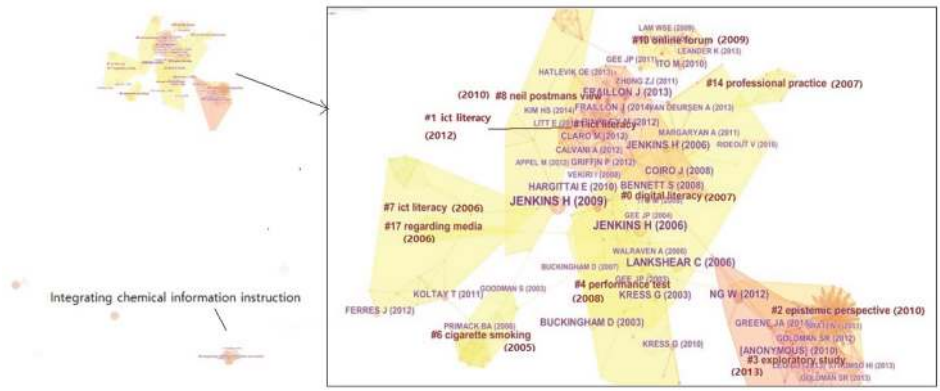

Figure 3. Entire and zoomed-in networks of clusters of co-cited publications. The color of the clusters demonstrates the year when the first co-citation occurred in the cluster (Chen, 2006), which is indicated in parenthesis in this figure. Yellow-green had the first co-citation in 2005, while the co-citation occurred in more recent years as the cluster's color gets closer to red-orange.

behavior. The clusters of co-authorships were primarily built in America and European countries.

Digital literacy is becoming a core competency that learners need to improve in diverse areas and age levels. Accordingly, learners at different ages should have adequate training to be able to communicate effectively and critically evaluate and obtain important information in their daily life (Gilster, 1997). They use technology and customized digital literacy curriculums that nurture digital literacy following their learning aims. Moreover, "digital literacy involves more than the mere ability to use software or operate a digital device; it includes a large variety of complex cognitive, motor, sociological, and emotional skills, which users need in order to function effectively in digital environments" (Eshet-Alkalai, 2004). Learners cultivate their understanding of the social impact of exploiting the technology and their computational thinking, which is required in maker movement and software education (Dougherty, 2012; Jenson & Droumeva, 2016). Also, to increase the originality of digital literacy-related studies, researchers may collaborate with other researchers from different countries and cultures to investigate a broader range of digital literacy environments.

Limitations of the current research should also be mentioned with suggestions for future research. First, this paper analyzed one finite chunk of a dataset, which was obtained by searching the four keywords at once. Further studies will split up the data by topic word and expand the relevant topics (e.g. Mahieu et al., 2018), for example, data literacy, computing literacy, analytic literacy, and infrastructure literacy, in order to more precisely investigate the similarities and differences

between the related concepts (Eshet-Alkalai, 2004). The data will also be retrieved from other disciplines and sectors beyond the scope of education (e.g. Park & Nam, 2017). Besides, the future study should trace the change of the leading research themes by time spans. Although this paper showed the clusters of co-occurring keywords and co-cited publications by timeline, that was not entirely adequate to unveil the detailed flow and aspects of digital literacy changes. Thus, further studies need to classify the dataset by period to look into the academic features and growth of this field more precisely.

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Appendix

Table 1. Co-occurring keywords in Clusters.

Cluster 1 (78 co-occurring keywords)			
Achievement	Adult learning	Age	Attitudes
Behavior	Beliefs	Challenges	Classroom
Community	Competence	Computer	Computer literacy
Computer self-efficacy	Computer use	Computer-mediated communication	Constructionism
Context	Design	Digital competence	Digital divide
Digital literacy	Digital media	Digital natives	Divide
E-learning	Education	Elementary education	Environment
Environments	Evidence-based practice	Family	Framework
Gender	Gender differences	Gender-differences	Higher education
Higher-education	Home	ICT	ICT literacy
Impact	Improving classroom teaching	Informal learning	Information
Information literacy	Instruction	Integration	Internet skills
Internet use	Learning	Lifelong learning	Media in education
Metaanalysis	Model	Natives	Online
Pedagogical issues	Perceptions	Performance	Perspective
Preservice teachers	Program	Satisfaction	School
School-students	Secondary education	Seeking	Self-efficacy
Social capital	Social networks	Students	Teachers
Teaching/learning strategies	Technology	University	Validation
Validity	Web		
Cluster 2 (43 co-occurring keywords)			
Adolescents	Advertising	Association	Audiences
Behaviors	Children	Cigarette-smoking	Citizenship
Civic engagement	Collaborative learning	Competences	Consumption
Critical media literacy	Critical thinking	Democracy	Digital literacy practices
Empowerment	Exposure	Facebook	Initiation
Intervention	Literacy	Media	Media competence
Media education	Media literacy	New media	Participation
Prevention	Programs	Risk	Schools
Smoking	Social media	Social networking	Teacher training
Technologies	Television	Tobacco	Tobacco use
Web 2.0	Youth	United-states	
Cluster 3 (30 co-occurring keywords)			
Adolescence	Adult	Audience	Case study
Childhood	College	Critical analysis	Critical literacy
Critical pedagogy	Digital	Early adolescence	Ethnography
Film	Information and communication technologies	Informational text	Instructional technology
Libraries	Literacies	Music	New literacies
Popular culture	Qualitative	Reading strategies	Research methodology
Sociocultural	Specific media	Teaching strategies	Texts
Theoretical perspectives	Visual literacy		

Cluster 4 (19 co-occurring keywords)			
Early adolescence	Adolescence	College	Adult
Adolescent	Materials	Content literacy	Domain knowledge
Engagement	Identity	Information literacy	Instructional strategies
Media literacies	Methods	Motivation	Professional development
Teacher education	University students	Writing	
Cluster 5 (18 co-occurring keywords)			
Chemical information	Chemoinformatics	Communication	Communication/writing
Courses	Curriculum	First-year undergraduate/ general	Inquiry-based/discovery learning
Internet/web-based learning	Learn	Organic chemistry	Problem solving/decision making
Science	Scifinder scholar	Second-year undergraduate	Skills
Student-centered learning	Upper-division undergraduate		
Cluster 6 (12 co-occurring keywords)			
Contexts	Culture	English	Issues
Language	Literacy practices	Multiliteracies	Pedagogy
Policy	Reading	Singapore	Multimodality
Cluster 7 (12 co-occurring keywords)			
Assessment	Comprehension	Credibility	Epistemological beliefs
Inquiry	Internet	Knowledge	Personal epistemology
Prior knowledge	Readers	Strategies	Text