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Exploring four decades of research in *Computers & Education*

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ABSTRACT

A content analysis of abstracts and titles of 3674 full papers in *Computers & Education* published between 1976 and 2016 was conducted in order to a) identify and analyze their thematic and conceptual flow, b) how these reflected the evolving technologies and theories and c) how the research topics and concepts semantically related to each other. Abstracts and titles can be considered appropriate for such conceptual analysis since they are lexically dense and focus on the core issues presented in articles. Based on a relational concept analysis using a text-mining tool, the study revealed that over the course of these 40 years, the articles progressed through four distinct stages, reflecting major developments in educational technology and theories of learning with media: the advancement and growth of computer-based instruction (1976–1986); stand-alone multimedia learning (1987–1996); networked computers as tools for collaborative learning (1997–2006); and online learning in a digital age (2007–2016). The paper concludes by suggesting that such mapping and analysis of the literature in this and other fields of educational technology, including non-English language journals, books and conference proceedings, can provide a valuable overview of research and scholarship for communities of practice and inquiry around the globe.

1. Introduction

The 20th century witnessed an explosion in the digital information and communications technologies (ICTs), leading to the concept of the 'information society' (Machlup, 1962). While media research dates back to early part of that century (Saettler, 2004), the field of instructional and educational technology is a relatively young academic discipline with scholarly journals in related fields only starting to appear in the 1970s. Such journals serve as important communication systems which reveal the intellectual nature of particular scientific knowledge networks (Garfield, 1972).

By the time the journal *Computers & Education* was launched in 1976, computer-based (behaviorist) instruction was being trialled in US and UK schools, the UK Open University (1969) and Microsoft (1975) had been founded; Apple was launched the year following, in 1977. In the UK, the Council for Educational Technology (CET) had been established in 1967, defining educational technology as the development, application and evaluation of systems, techniques and aids to improve the process of human learning (CET, 1972). Shortly thereafter, in 1969–70 the US Association of Educational Communications and Technology (AECT) had transitioned from an audiovisual to an instructional technology orientation and was concerned with "the theory and practice of design, development, utilization, management, and evaluation of processes and resources for learning" (Seels & Richey, 1994, p. 1).

During the lifetime of *Computers & Education,* technology has changed the world. Computing has progressed from the mainframe

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era to the microcomputer era to the Internet era, and as the U.S. Office of Educational Technology (2017) states, "the conversation has shifted from whether technology should be used in learning to how it can improve learning to ensure that all students have access to high-quality educational experiences." (¶12).

Lee, Driscoll, and Nelson (2004) state that "understanding trends and issues in terms of topics and methods is pivotal in the advancements of research" (p. 225). Content analysis is an invaluable means of interpreting and coding the content of a research discipline and identifying gaps and priority areas for future research. As West (2011) observes,

> There is practical value to understanding where we are right now, and where we have been in the very recent past. To understand this, it can be helpful to review some of the journals in our field to see what conversations are being held, research being conducted, tools being developed, and theories being accepted. (p. 60).

Much can be learned from studying the changing accounts, perspectives, voices and interpretations of theory, findings and practice in such a journal as *Computers & Education*. Research on distance education which is "institution-based, formal education where the learning group is separated, and where interactive telecommunications systems are used to connect learners, resources, and instructors" (Simonson, Schlosser, & Orellana, 2011, p. 126), is closely related to the field of educational technology. Zawacki-Richter and Naidu (2016) conducted a content analysis of *Distance Education*, a journal which ranks #20 in the Thomson Reuters 2015 Citation Report "Education and Educational Research" category, with an impact factor of 2.021. By analyzing 515 research articles published between 1980 and 2014, they were able to identify the following main themes over seven 5-year time periods: professionalization and institutional consolidation (1980–1984), instructional design and educational technology (1985–1989), quality assurance in distance education (1990–1994), student support and early stages of online learning (1995–1999), the emergence of the virtual university (2000–2004), collaborative learning and online interaction patterns (2005–2009), and interactive learning, MOOCs, and OERs (2010–2014). In a recent study, Zawacki-Richter, Alturki, and Aldraiweesh (2017) analyzed 580 articles published between 2000 and 2015 in the *International Review of Research in Open and Distributed Learning* (IRRODL). They identified three broad themes emerging over this fifteen-year period: the establishment of online learning and distance education institutions (2000–2005); widening access to education and online learning support (2006–2010); and the emergence of Massive Open Online Courses (MOOCs) and Open Educational Resources (OER) (2011–2015). Similar reviews have been carried out on key journals in other disciplines, such as psychology (Cretchley, Rooney, & Gallois, 2010) and business administration (Liesch, Håkanson, McGaughey, Middleton, & Cretchley, 2011).

Computers & Education is one of the oldest, most established and prestigious journals in the field of educational technology and computer-assisted learning with a high impact in terms of citations. Its purpose, as stated on the Elsevier website[1] is to: "increase knowledge and understanding of ways in which digital technology can enhance education, through the publication of high quality research, which extends theory and practice".

This study sought to a) identify and analyze the thematic and conceptual flow of all articles published in *Computers & Education* b) consider how these reflected the evolving technologies and theories and c) discover how the research topics and concepts semantically related to each other. In so doing, it also aimed to identify priorities for future research in support of the advancement of knowledge in the field.

2. Sample and method

2.1. Papers published in Computers & Education

All of the research articles published in *Computers & Education* between 1976 and 2016 ($N = 3674$) were analyzed for the purposes of this study. Book reviews and editorial notes were excluded from the sample. Table 1 details the number of papers published annually in the journal.

In this time, the journal has gone from print only to print plus online publishing (in 1998) and to include open access articles. *Computers & Education* is also a very international journal. Published articles came from 79 different countries, but the USA, UK, Taiwan and Spain accounted for over 50% of the publications (see Appendix A) and overall, 1974 (64.4%) of the leading authors were men and 1089 (35.6%) were women, taking the sex of the first author into consideration. 2015 was the only year in which women contributed more papers as first authors than men (see Appendix B).

Out of the 231 journals listed in the 2015 Thomson Reuters Journal Citation Reports "Education and Educational Research" category, *Computers in Education* ranked #9 with an impact factor of 2.881. Appendix C lists the 20 most cited articles.

2.2. Computer-assisted content analysis

Content analysis examines the conceptual structure of text-based information and detects the most frequently occurring themes within large amounts of data (Krippendorff, 2013). Fisk, Cherney, Hornsey, and Smith (2012) conclude that computer-aided content analysis is a suitable method by which to map a field of research. For the purposes of this study, the content analysis software Leximancer™ (2011) was used to produce a set of concept maps revealing the semantic structure of the themes and key concepts within articles published in *Computers & Education*. Leximancer™ has been used for the content analysis of a number of academic

[1] https://www.journals.elsevier.com/computers-and-education (accessed: April 14, 2017).

Table 1
Number of articles published in *Computers & Education* by year.

Year	Issues	N	Year	Issues	N
1976	1	6	1997	8	41
1977	3	18	1998	8	53
1978	4	27	1999	8	33
1979	4	41	2000	8	39
1980	4	28	2001	8	43
1981	4	22	2002	8	42
1982	4	51	2003	8	46
1983	4	26	2004	8	47
1984	4	70	2005	8	48
1985	4	28	2006	8	56
1986	4	59	2007	8	123
1987	4	30	2008	8	230
1988	4	74	2009	8	209
1989	4	47	2010	8	277
1990	8	96	2011	8	229
1991	8	81	2012	8	238
1992	8	81	2013	10	287
1993	8	69	2014	10	217
1994	8	71	2015	11	227
1995	8	54	2016	12	164
1996	8	46			
Total					3674

journals, including the *Journal of Cross-Cultural Psychology* (Cretchley et al., 2010), *Journal of International Business Studies* (Liesch et al., 2011), the *International Review of Research in Open and Distributed Learning (IRRODL)* (Zawacki-Richter et al., 2017), *Distance Education* (Zawacki-Richter & Naidu, 2016), and the *Journal of Communication* (Lin & Lee, 2012).

The software locates core concepts within textual data (conceptual analysis) and identifies how these concepts inter-relate (relational analysis) by the frequency with which words co-occur in the text. Leximancer™ then produces a visual map, which clusters similar concepts that co-occur in close proximity. Smith and Humphreys (2006) explain that: "The map is an indicative visualization that presents concept frequency (brightness), total concept connectedness (hierarchical order of appearance), direct interconcept relative co-occurrence frequency (ray intensity), and total (direct and indirect) interconcept co-occurrence (proximity)" (p. 264). Thematic regions are formed depending on the connectedness of concepts and are then given the name of the most prominent concept in that group.

Leximancer™ has been shown to produce stable results, such as the analysis by Harwood, Gapp, and Stewart (2015), which revealed that the software produced similar results to those derived from a manual grounded theory analysis. However, they advise that "Leximancer™ is not a panacea, it still requires analytical sensitivity and judgment in its interpretation, but it is straightforward to probe the data and cross-check via the resultant maps. […]. Leximancer™ enables the analyst to make sense of large narrative data sets with minimal manual coding" (p. 1041). The interpretation of the concept maps produced by the textmining tool requires a thorough understanding and knowledge of the context and topic under examination.

The abstracts and titles of all the research articles published in *Computers in Education* between 1976 and 2016 were collected from the publisher's journal website. Titles and abstracts are considered appropriate for such conceptual analysis since they are "lexically dense and focus on the core issues presented in articles" (Cretchley et al., 2010, p. 319). Other bibliographic analyses are based on abstracts and titles as well, such as the content analysis of *IRRODL* from 2000 to 2015 (Zawacki-Richter et al., 2017) and *Distance Education* from 1980 to 2014 (Zawacki-Richter & Naidu, 2016). Bell, Campbell, and Goldberg (2015) conducted a review about professional identities of nurses with Leximancer™ based on abstracts and keywords from the PubMed Medial Research Database.

The abstracts and titles from 3674 full papers, and subsets of data in four 10-year periods were obtained as follows: 1976–1986 (376 articles),[2] 1987–1996 (649 articles), 1997–2006 (448 articles), and 2007–2016 (2201 articles). The text-mining tool was used to analyze both the entire data set from 1976 to 2016 and each 10-year time period separately.

2.2.1. Limitations

Although *Computers & Education* is a leading journal with a long publication history, we acknowledge that our enquiry focused on the structure and flow of research topics in educational technology through the lens of a single journal and one which draws the majority of its publications from the English-speaking world. Other comparable journals in the field, as well as books, dissertations and conference proceedings in English and other languages should be considered in further studies to map the research domain of educational technology. In order to reduce the limitation of focusing on a single journal, the findings are compared and contrasted

[2] The first issue of *Computers and Education* was published at the end of 1976. This issue was added to the first 10-year time period from 1977 to 1986.

with other studies into journals with a similar focus using the same methodological approach in section 3.6 (*Computers & Education* in the context of other journals in the field).

Furthermore, we acknowledge that the titles adopted for the description and analysis of the four decades are very broad. They highlight the most prevalent trend in each time period. During this time, there are obviously a number of subtopics, some of which did not last and some of which evolved into major topics.

As described above, Leximancer™ produces concept maps that are based on algorithms to identify the most frequent terms (concepts) in a body of text and the relationships between these concepts. The application of such a co-word analysis for the mapping of a research discipline has been subject of debate. Leydesdorff (1997) made the point that "the subsumption of phenomenologically similar words and other textual signals under keywords or other concept symbols assumes stability in the meanings of the indicated concepts" (p. 426), but words can change in terms of meanings from one context to another or in terms of frequencies of relations with other words. He concluded: "The fluidity of epistemic networks in which nodes and links change positions may destabilize any knowledge representation on the basis of co-occurrences of words" (p. 426). On the other hand, Courtial (1998) responded that words in a co-word analysis are just used as indicators of links between concepts and not as linguistic items to mean something.

The prevailing opinion in the literature is that the co-occurrence of words provides "useful information for a narrative inquiry on a subject" (Liesch et al., 2011, p. 24; see also; Sowa, 2000; Stubbs, 1996). van Raan and Tijssen (1993) praise the potential of bibliometric maps based on co-word analysis to visualize complex masses of data in less time and "they also accomplish data reduction while retaining essential information" (p. 175). However, they also contend that such science maps need thorough interpretation and knowledge of the subject matter.

However, in the light of Leydesdorff's concerns, we provide qualitative examples for the main emerging research topics or "concept paths" in order to illustrate the representativeness between the terms in the concept maps and the flow of themes and topics in each map over 40 years.

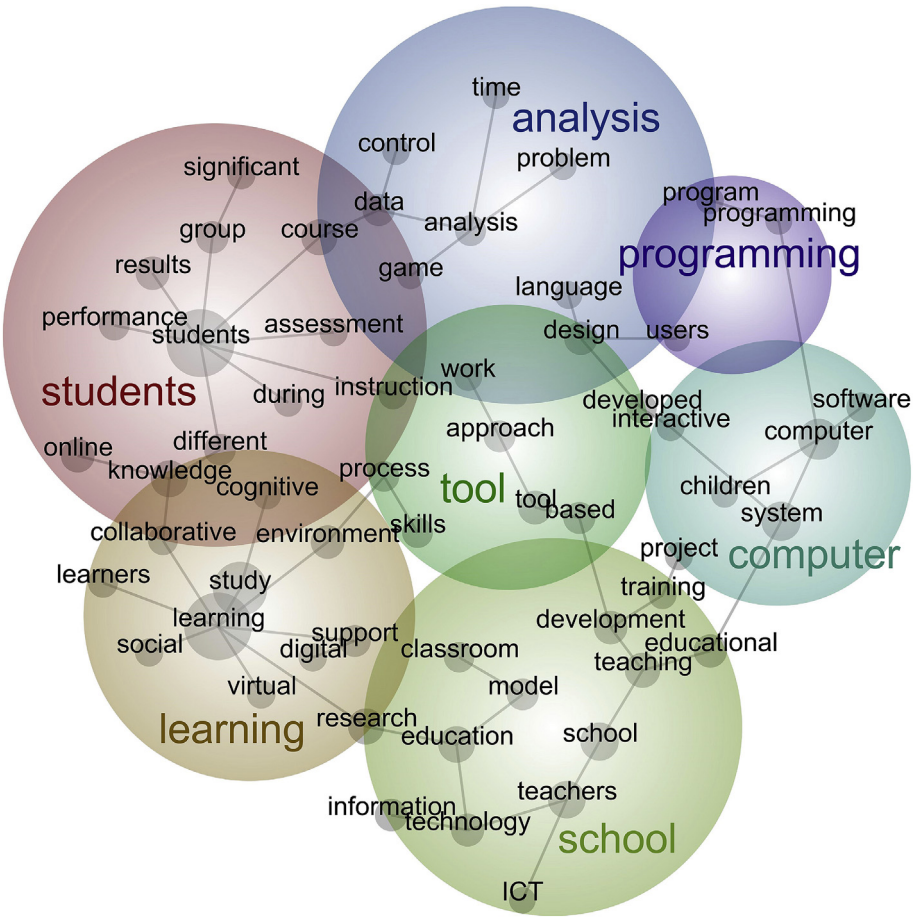

Fig. 1. Overall concept map (N = 3,675 articles published between 1976 and 2016).

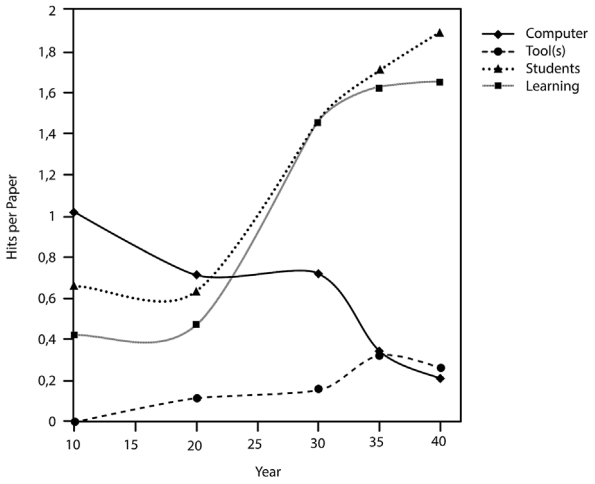

Fig. 2. Development of frequent terms over time standardized by hits per paper.

3. Results and discussion

3.1. Overall scope of the journal (1976–2016)

Fig. 1 depicts the major themes covered in the articles published during the four decades of *Computers & Education* (1976–2016). The thematic summary includes a connectivity score to indicate the relative importance of the themes: *students* with 9432 direct mentions within the text (=100% relative count), followed by *learning* (93% connectivity), *school* (84%), *tool* (58%), *computer* (52%), *analysis* (36%), and *programming* (9%).

The journal publishes research articles about the use of computers as a tool for learning (see thematic region of *tool* in the center of the concept map), e.g. for computer-mediated communication (Mason & Bacsich, 1998; Steeples, Goodyear, & Mellar, 1994). Emphasis is placed on studies on the design and evaluation of computer-based learning environments, systems, programs and courses and the integration of information and communication technologies (ICT) for teaching and learning in various subject domains (e.g. Phillips, 1982; Tüzün, Yılmaz-Soylu, Karakuş, İnal, & Kızılkaya, 2009; Wei, Peng, and Chou (2015).

Regarding the educational sectors addressed in the publications, emphasis is placed on schools/K-12 and higher education settings: The search terms “school” and “K-12” in all titles and abstracts produce 2871 hits and the terms “university” and “higher education” 1254 hits. In contrast, 757 hits are retrieved for “training” and “professional development”, and here the focus is largely on teacher training in schools rather than in the corporate world. A search for “informal learning” and “non-formal learning” revealed only 14 hits.

There are several recurring concepts in the four time periods under investigation, and these include *computer*, *students*, *ICT*, *schools, model* or *learning*. They encapsulate broad and common thematic areas canvassed throughout the whole time period. In the following analysis and interpretation, emphasis is placed on new and emerging concepts in order to describe the shifting trends over the time period.

As will be shown in more detail in the following sections, there is a shift throughout the lifetime of the journal from a focus on computers and technology for computer-based instruction to a view of computers as tools for collaborative learning and the adoption of student-centered approaches to instructional design and learning. Fig. 2 illustrates this development, plotting the standardized frequencies of the concepts *computer*, *tool(s)*, *students*, and *learning* over time.

3.2. The advancement and growth of computer-based instruction (1976–1986)

The decade beginning 1976 saw many millions of personal computers (PCs) being used worldwide. However, mainframes, minicomputers and computer learning centres were still widely in use. The ‘computer literacy’ movement was born and computer assisted learning (CAL) was being introduced into schools but with the emphasis on teaching children to program and drill and practice learning and behaviorist and cognitive approaches to instructional design. Microsoft released the text-processing system Word in 1983, and the operating system Windows in 1985. CD-ROMs, simple simulation programmes for PCs and computer-based tutorials and educational games were becoming available and there was increasing convergence of instructional design, educational media and CAL.

After the beginnings of research into computer-based educational technology in the 1960s (see Vinsonhaler & Bass, 1972), the first decade of publications in *Computers & Education* reflects the advancement and growth of computer-assisted learning with *computer* as the most prominent concept (100%), followed by *students* (79%), *system* (73%), *data* (8%), *information* (7%), and *teachers* (6%) (see Fig. 3).

The concept path *computer – learning – CAL and – teaching – system* forms the spine of the concept map. The authors were

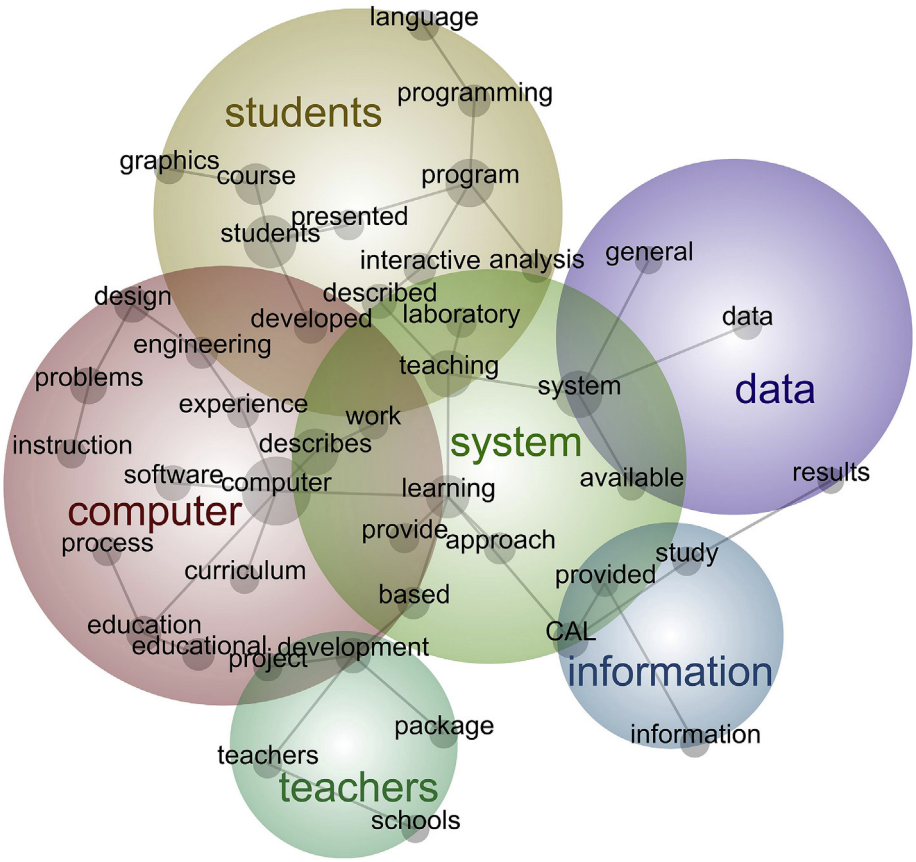

Fig. 3. Concept map for the time period between 1976 and 1986 (N = 366 articles).

discussing appropriate uses and the capabilities of computer systems in education (e.g. Milner & Wildberger, 1977), showing an interest in CAL in specific domains and particularly in the STEM subjects: mathematics, physics, chemistry or engineering (Ayscough, 1976; Hinton, 1978; Phillips, 1982) and teaching programming languages (Shneiderman, 1977). In the second half of the decade more studies were being carried out with regard to the use of language laboratories for modeling correct speech in second language learning, enabling students to practice privately and teachers to save time on routine practice (see Farrington, 1982).

As the thematic region of *information* shows (see concept path *information – provided – CAL – study – results*) many studies were concerned with evaluating CAL programs in order to inform the policy-makers. As Kidd and Holmes (1984) observed: "Teachers, school administrators and funding agencies are often reluctant to support the acquisition of a CAL facility unless some sort of statistical evidence can be brought forth that will prove the desirability of CAL" (p. 77). The dream of a computer revolution in schools and higher education and the educational effectiveness of CAL was being questioned by Kulik, Kulik, and Cohen (1980) in an early meta-study published in the *Review of Educational Research*. Examining 59 independent evaluation studies, they concluded that "for the most part the computer has made a small but significant contribution to the effectiveness of college training. In the typical implementation, computer-based instruction raised examination scores by about 3 percent points, or about one-quarter standard deviation" (p. 537).

The adoption of CAL in schools was still in its early stages (see *project – development – teachers – schools*) and there was still the question of how to integrate computer literacy with the curriculum. In order to provide guidelines for curriculum planners Cheng and Stevens (1985) reported on how teachers prioritized the knowledge and skills that their students needed to become 'computer literate' and Shaw, Swigger, and Herndon (1985) reported on the kinds of questions that children asked while learning to use the computer. Another issue under discussion was the professional development of teachers. As Keil (1979) pointed out, "The distribution of computers in German schools has reached a point where coordination of the activities and support of the teachers is indispensable" (p. 17). Interestingly, even at this early stage, the question of privacy was being raised. Hussain (1979) questioned whether, with cheaper mass data storage equipment and computers processing data at greater speeds, there was a danger of the security of student data being violated.

3.3. Stand-alone multimedia learning (1987–1996)

The late 1980's saw the development of laptops. In 1990 Tim Berners-Lee invented the World Wide Web and created the first

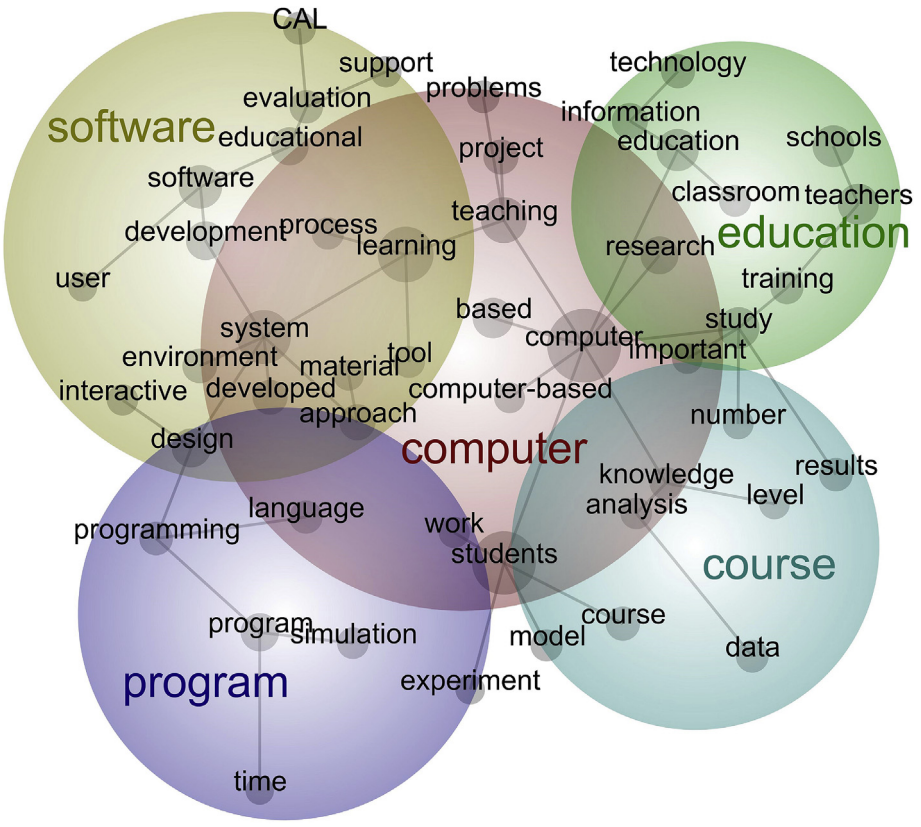

Fig. 4. Concept map for the time period between 1987 and 1996 (N = 648 articles).

webpage. In the 1990s, multimedia PCs were developed, simulations, educational databases and other types of CAL programs became available on CD-ROMs, many with animation and sound. Schools were using videodiscs, object-oriented multimedia authoring tools were in use. By 1992, the Internet had one million hosts, computers were nine orders of magnitude faster and network bandwidth was twenty million times greater. 1993 saw the first Smartphone, and the Netscape browser was launched. New businesses (such as Amazon or eBay), schools, and individuals were creating web pages and many educational institutions were rewiring for Internet access. There was even the first learning management system (Virtual-U), developed at Simon Fraser University in Canada. However, the vast majority of computers at this time were not connected to the Internet and still relied on stand-alone software applications. As the decade progressed, educational practice and the use of computers transitioned to more student-centered approaches such as discovery, problem-based and collaborative learning in the light of advancements in educational and cognitive psychology (see Davis, 1990; Magill et al., 1988).

Throughout this decade, researchers were increasingly questioning the usefulness and design of CAL programs in different subject areas and stressing the need for further research into integrating the new tools and methods in schools and higher education. The number of articles almost doubled from 366 in the first decade to 648 in this period. The concept map now depicts five major themes: *computer* (100%), *software* (60%), *education* (59%), *course* (41%), and *program* (32%). The *computer*, connected with *students*, *teaching*, *learning* and *education*, forms the central thematic region, which overlaps with all other content areas (see Fig. 4).

The challenges of implementing CAL in school classrooms remained a major concern (*computer* connected with *technology* – *information* – *education* – *classroom*). Cicchelli and Baecher (1987) noted: "The introduction of computers in the schools represents a dramatic change" (p. 85). Chandra, Bliss, and Cox (1988) addressed general management issues relating to the introduction of computers in schools and other studies examined the views and attitudes of teachers and departmental heads, organizational constraints such as insufficient time, large classes and limited resources and the lack of professional development in CAL for teachers (*study* – *training* – *schools*). Cox, Rhodes, and Hall (1988) emphasized that appropriate initial training for teachers was critical for the uptake of CAL in schools and Thompson (1991) concluded that "long and sad experience has shown that if the training of teachers is neglected, the learning process with computers can be more costly and less effective than with traditional methods" (p. 1).

Other articles focused on the design, usage and evaluation of CAL software for teaching and learning (see concept path *computer* – *teaching* – *learning* – *systems* – *development* – *software* – *educational* – *evaluation*). For example, after evaluating a CAL project at the M.I.T. Department of Ocean Engineering Denson and Yue (1989) concluded that if it was to achieve its objectives, "the software must also have tutoring features which will guide the students in learning the material" (p. 279). In another article, Boutzev and Boutzev (1990) discussed the instructional design principles necessary to improve the quality of CAL-based electrical engineering education.

And for the first time, Horney (1993) dealt with the design of a learning environment based on hypertext.

Right in the middle of this period, an updated meta-analysis by Kulik and Kulik (1991) again revealed that CAL was failing to prove its effectiveness with 150 out of 248 studies showing no significant positive effects on student achievement. Such comparison studies led to the famous media debate between R. E. Clark and R. B. Kozma about the influence of media on learning (see Carter, 1996, for a succinct summary of the discussion). However, despite all this debate, most of research continued to be technology-focused and driven by the innovations in ICT (see concept path *computer – education – information – technology*). So not surprisingly, the concept of students does not form a thematic area of its own. It sits at the periphery of the thematic region of *computer*. This will change during the next decade as research projects begin to place the learners at the center of their considerations and explore the opportunities for new forms of learning such as computer-supported collaborative learning (see David Whittington, 1996).

3.4. Networked computers as tools for collaborative learning (1997–2006)

In the years following 1997, the Internet expanded faster than predicted and became the world's largest database of information. Search engines such as Google and Yahoo constantly developed new ways of accessing information in the ever-growing number of web pages. Internet-based publishing, discussion forums and personal pages became common. Educational software became more motivating and effective for learning with the incorporation of graphics and video. Increased computer storage capacity and use of CD-ROM and DVD drives in computers made it easier to store multi-media educational programs. The learning management system WebCT was released in 1997. SMS was being used widely. There were opportunities for people to learn and take degrees online. The term 'e-learning' was introduced and the business world was increasingly using this mode for staff training. Wikipedia was launched in 2001, and the MIT OpenCourseWare proof-of-concept pilot site was opened to the public, offering 32 courses in 2002. The term open education resource (OER) was coined (see UNESCO, 2002, 2012) and the interactive potential of social media and Web 2.0 applications was becoming understood (Beldarrain, 2006). Furthermore, Moodle 1.0, BlackBoard, Facebook, Google, YouTube and the Khan Academy were all launched during this time period.

In this third decade, the thematic focus of the *Computers & Education* articles was changing: the term now most commonly featuring is *learning* (100%), closely followed by *students* (97%), and then at some distance, by *course* (57%), *education* (37%), *school*

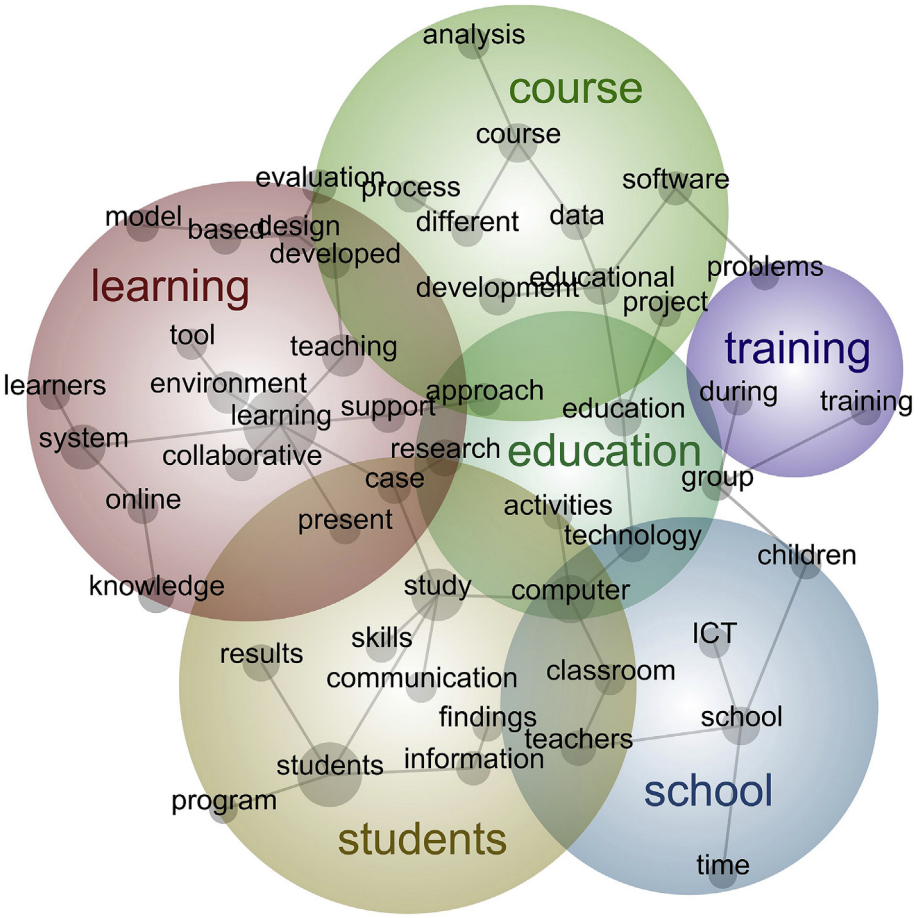

Fig. 5. Concept map for the time period between 1997 and 2006 (N = 448 articles).

(24%), and *training* (7%). As the concept map in Fig. 4 reveals, the term *computer* is no longer dominant in the thematic region of *education* (see Fig. 5). The issues in the surrounding areas are now the major focus in the publications with learning and students as the most important themes.

With the growing interest in cognitivism and constructivism, researchers now acknowledged that learning is a social exercise and that the computer is not simply a tool for disseminating information and knowledge but for communication and collaboration, something made increasingly possible by the revolutions in the technology. Jonassen, Campbell, and Davidson (1994) contended that Clark and Kozma had been debating the wrong issue, and that researchers should be focusing on the capabilities and characteristics of media for learning rather than for teaching. They argued that both teachers and learners were involved in a complex mediated learning process wherein computers, media and technologies are cognitive tools and "intellectual partners in the knowledge construction process" (p. 38).

The *Computers & Education* articles of this time resonated with these theoretical considerations. As the map shows, the most frequent concept of *learning* is closely connected with *collaborative*, *environment*, and *tool*. Authors such as Hmelo-Silver (2003), Schrire (2006), and Weinberger and Fischer (2006) deal with the design and orchestration of collaborative knowledge construction in 'knowledge building communities' (see Scardamalia & Bereiter, 1992).

The authors were still concerned with the development of educational software (see concept path *computer – technology – education – software*) and design of interactive and authentic "hypermedia" environments (e.g. Calcaterra, Antonietti, & Underwood, 2005; Hill, Bailey, & Reed, 1998) in support of self-directed learning. The implementation of ICTs in schools remained an important topic (e.g. Mooij & Smeets, 2001; see *classroom – teachers – school – ICT*), including the *training of teachers* (see e.g. Murray, 1998). However, there was a clear shift towards research into online learning and web-based systems, especially at higher education institutions introducing learning management systems like WebCT in the late 1990s. Concepts such as *learning*, *system*, and *online* were appearing in *evaluation* studies at the intersection of *learning* and *course*, and there was growing emphasis on web-based courses (e. g. Rowe & Gregor, 1999; Tao, Guo, & Lu, 2006).

As Jonassen, Davidson, Collins, Campbell, and Haag (1995) observed, in constructivist learning environments, knowledge and meaning are created and negotiated through communication and collaboration and so applications of various digital tools for asynchronous or synchronous communication start to play a prominent role in the research into learning design (see concept path *computer – study – communication*). The first *Computers & Education* paper to mention the term computer-mediated communication (CMC) was written by Steeples et al. (1994). There followed rich discussion about CMC and many studies addressed the issue of online interaction and communication. Researchers were clearly fascinated by the opportunities for collaborative online learning afforded by the new ICTs. For example, the UK Open University (OU) had introduced online tutoring in the mid 1980s, using a system called CoSy (Conferencing System) (see Mason, 1989) and Mason and Bacsich (1998) reviewed 10 years of experience of the use of CMC at the OU.

As CMC is mainly text-based, the data is easily accessed for content analysis. Many studies analyzed online interaction patterns in order to better understand the online learning processes and improve "e-moderation" (Salmon, 2000), the use of e-mails (e.g. Hassini, 2006; Russell & Cohen, 1997) and synchronous chat and CMC in virtual worlds (Ingram, Hathorn, & Evans, 2000). And greater emphasis was now being placed on the role, characteristics and behaviors of *students*, in researching learning design. For example, Wilson (2000) correlated personality types and other learner characteristics with communication behavior in CMC and face-to-face communication.

3.5. Online learning in a digital age (2007–2016)

2007 saw the launch of the iPhone, the Web becoming mobile and the release of the e-book reader, Kindle. In 2008 the first massive open online course (MOOC) was offered (Bozkurt, O¨zdamar Keskin & de Waard, 2016). In 2010 the iPad was launched and the rapidly growing use of smartphones, social media and wifi gave rise to a whole range of new interactive and participative mobile learning programmes. Learners quickly became acquainted with these new tools; in contrast with the early days of educational computing, many learners came to learning tasks already familiar with interfaces and well versed in using them to find information, learn, create and collaborate. In 2011 Stanford University offered three free online courses to over 160,000 students around the world. There followed a whole new range of educational providers such as Udacity and Coursera and proprietary and non-proprietary MOOC platforms designed to increase access and equity, attract mass audiences and market educational wares.

Digital media had assumed a far greater importance in all aspects of life, including education, employment, economics, communication, travel, entertainment and the environment – a social process described as 'the digital turn' (Mills, 2010). In line with this, the last decade of *Computers & Education* saw a major transformation. The themes of the articles include *system* (100%), *group* (96%), *technology* (86%), *design* (84%), *computer* (39%), *e-learning* (14%), and *feedback* (9%) (see Fig. 6).

E-learning (first mentioned by Lupo & Erlich, 2001) was moving into mainstream educational provision. Higher education in particular was adopting these means, both on and off campus (see concept path *e-learning – system – university* and *student – course – online – learners*). Many studies now investigated web-based learning and teaching platforms (e.g. Ngai, Poon, & Chan, 2007), the transition from traditional to online course delivery (e.g. Barak, 2007) and the importance of learner support, assessment and feedback in online environments. So much so that *feedback* connected with *assessment* formed a thematic region of its own. Articles dealt for example with the design of computer-based, automated feedback in areas such as problem solving (Corbalan, Paas, & Cuypers, 2010). Interactive, collaborative learning was also becoming a central topic (see *collaborative – environment – virtual – interactive*). Thus Wei et al. (2015) asked, "Can more interactivity improve learning achievement in an online course?" (p. 10), examining the impact of learners' use of the interactive features of a course management system (CMS) on their online learning

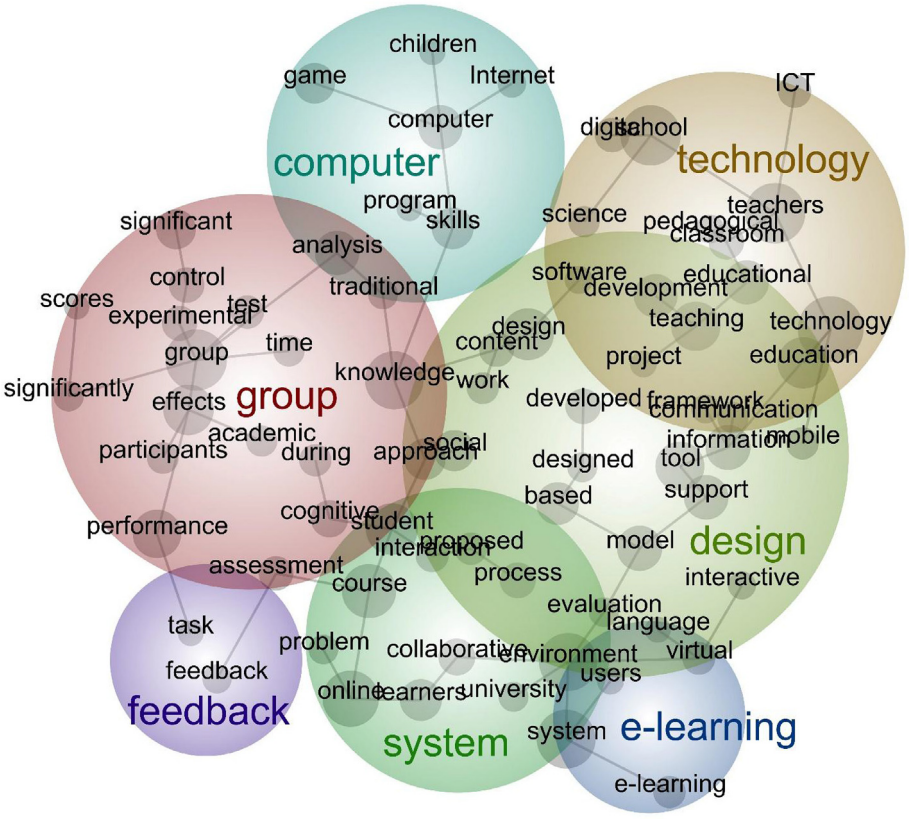

Fig. 6. Concept map for the time period between 2007 and 2016 (N = 2201 articles).

performance. The thematic regions of *technology* and *design* overlap and are connected via the concept path *tool – communication –teaching– software*.

The use of ICTs and digital media in schools remained an important research area (see *ICT*, *technology*, *classroom – teachers – schools – digital*). Children's knowledge and skills in using computers and the Internet became important topics with the rapid development of digital devices and applications and incorporation of ICT in all forms of teaching and learning (see *knowledge – skills – computer – children*, *Internet*). In a recent study Lee, Chen, Li, and Lin (2015) presented an instrument for measuring 'new media literacy' in youths designed to inform teaching practice in schools and other studies explored the opportunities for game-based learning in various areas including language learning (Liu & Chu, 2010), geography (Tüzün et al., 2009), motor skills (Hsiao & Chen, 2016) and sex education (Arnab et al., 2013).

The thematic region of *group* indicates a focus on experimental research designs in which the effects of different independent variables on outcome variables are tested with experimental and comparison groups. For example, Kim (2012) explored the impact of digital storytelling on academic achievement, critical thinking, and learning motivation of high school students.

Researchers continued to be fascinated by the new opportunities that ICTs and the Internet afford for collaborative online learning. With the proliferation of mobile devices, digital media and online learning many more researchers were being attracted to the field of educational technology, contributing to the growth of *Computers & Education*. In this last decade, more papers have been published in the journal than in the previous 30 years.

3.6. Computers & Education in the context of other journals in the field

As acknowledged above, this study analyzes the thematic flow of research areas through the structure and progression of research topics in educational technology in a single journal, albeit one that is a leading international publication with a long history of extending understanding and practice in applying digital technology to enhance education. In order to reduce this limitation, we can compare and contrast the current study concerning *Computers & Education* with previous content analysis of similar SSCI journals that publish papers in the field of educational technology, online, distance learning, and e-learning: *Distance Education* (1980–2014, see Zawacki-Richter & Naidu, 2016) and the *International Review of Research in Open and Distributed Learning* (*IRRODL)* (2000–2015, see Zawacki-Richter et al., 2017). Fig. 7 shows how the research areas progressed over time in *Computers & Education*, *DE* and *IRRODL*. A journal that started even earlier (in 1970) than *Computers & Education* is the *British Journal of Educational Technology* (BJET). Regrettably, a systematic content review of BJET that covers the whole time of publication is not available for BJET. In his editorial,

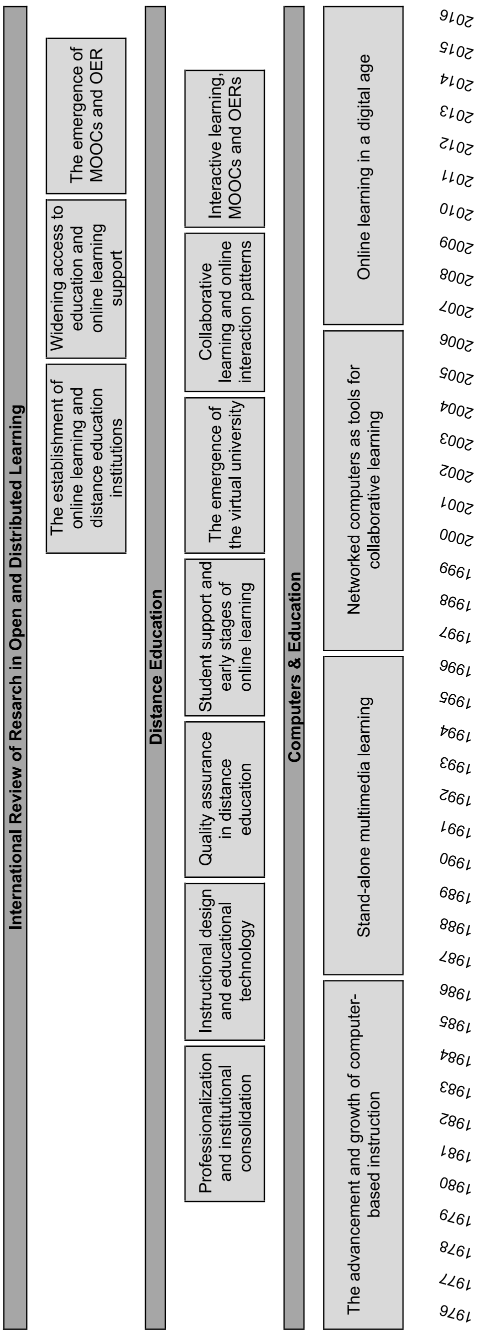

Fig. 7. Comparison of main themes in *Computers & Education*, *Distance Education* and *IRRODL*.

Latchem (2006) reported on a content analysis of articles in BJET between 2000 and 2005, but his focus was mainly on authorship patterns and research methods.

As described above, the four decades of publications in *Computers & Education* were characterized as "The advancement and growth of computer-based instruction", "Stand-alone multimedia learning", "Networked computers as tools for collaborative learning", and "Online learning in a digital age". In the first decade of the journal's operation the aim of many studies was to collect evidence on the effectiveness and impact of computer-based instruction on students' achievement in different subjects with the emphasis on STEM subjects and programming languages (e.g. Phillips, 1982; Shneiderman, 1977). The first meta-study by Kulik et al. (1980) revealed only minor effects and non-significant differences (see Kulik & Kulik, 1991). In the next decade, there was an emphasis on student-centered approaches and the professional development of teachers to achieve meaningful educational technology integration in the classroom (e.g. Cox et al., 1988; Thompson, 1991). With growing computer power and the availability of multimedia learning environments, researchers then began to turn their attention to investigating the different presentation modes for learning (e.g. Harding, Lay, Moule, & Quinney, 1995; Ropa, 1991). The first experiments were also being carried out with networked computers and hypertext (see Horney, 1993), but the majority of computer-based learning and training was delivered by stand-alone computers and CD-ROMs (e.g. Mayes, Kibby, & Watson, 1988; Miller, Blackstock, & Miller, 1994). The third decade saw a clear shift towards research into online learning and web-based systems, especially at higher education institutions introducing virtual learning environments and computer-mediated communication (e.g. Mason & Bacsich, 1998). Researchers were intrigued by the social affordances of the Internet for collaborative learning and online interaction. This development of digital transformation and "e-learning" continued and accelerated in the last decade with the proliferation of mobile devices and the emergence of Web 2.0 applications for social learning, e.g. to support student engagement (Junco, 2012).

The journal *Distance Education* (DE), founded in 1980, was one of the first journals to focus exclusively on research in the fields of open, distance and flexible education and it remains a primary source of scholarly work in these fields. *IRRODL* was established in 2000 with the aim of highlighting plausible or empirically determined theories, principles and practices in various forms of open and distance education. The thematic scope of *DE* and *IRRODL* is wider than *Computers & Education* as the field of open and distance learning is strongly influenced by the adult education and lifelong learning theory and practice. However, all of the foundation theorists of distance education (Peters, 1967, 1983), independent study (Wedemeyer, 1981), transactional distance (Moore, 1993), guided conversation (Holmberg, 2007) and community of inquiry (Garrison, Anderson, & Archer, 2000) in distance education foresaw that highly interactive electronic media and computers would permit more intensive, personal, individualized and dynamic dialogue between instructors and students and have impact on the extent and quality of the learning.

The majority of studies published in *DE* and *IRRODL* are in the context of higher education, whereas *Computers & Education* has published many articles about computer-based learning in schools. The establishment of *BJET* coincided with the development and opening of the Open University UK (OUUK), followed by other open and distance teaching universities in the 1970s (e.g. Athabasca University in Canada or the FernUniversität in Germany). After the first decade of practice, researchers in distance education were reflecting upon the experiences of these newly founded institutions and seeking to understand their organizational systems at the macro-level and the ways in which their operations differed from those in conventional campus-based institutions (see also McIntosh, Woodley, & Morrison, 1980; Jevons, 1984). Zawacki-Richter and Naidu (2016, p. 250) characterized this first period of *DE* from 1980 to 1984 as one of "professionalization and institutional consolidation".

In the second half of the 1980s researchers in *DE* began to focus on the core process of distance teaching institutions: instructional design and the use of educational technology to support learning at a distance in different subject domains, such as sociology (Nation, 1987), foreign languages (Holmberg, 1985) or history (Finkel, 1985). This resonates with articles in *Computers & Education* between 1976 and 1986, although the focus here was on computer-assisted learning in the STEM subjects at schools or for teaching programming languages (see section 3.2). In the UK, *BJET* was influenced at this time by research on (print-based) course material development alongside television and radio broadcasts (see Bates & Gallagher, 1976; Lewis, 1971) at the OUUK, but research also explored telephone conferencing (e.g. Turok, 1975), and best practice in choosing and integrating media into courses (e.g. Bates & Pugh, 1975).

Further major research topics that emerged over time in *Computers & Education* are also mirrored in other educational technology and distance learning journals, for example the important issue of quality assurance and evaluation of teaching and learning with (multi-)media (e.g. Mann, 1998) and the theoretical shift from behavioral approaches to computer-based learning to constructivist assumptions and collaborative learning as a social and communicative activity in the online environment (e.g. McLinden, McCall, Hinton, & Weston, 2006; Fahy, 2007).

Whereas publications in *Computers & Education* emphasize topics that are related to the micro-level of teaching and learning with computers and interactive media (see section 3.5) articles in distance education journals are more concerned with opportunities that online learning affords for widening access to (higher) education. For example, studies into the pros and cons of massive online open courses (MOOCs) and open education resources (OER) featured prominently in issues of IRRODL and DE after 2010 (see Zawacki-Richter & Naidu, 2016).

By and large, this brief comparison indicates that the results and findings presented here about the flow and trends of research topics in *Computers & Education* resonate with the thematic scope of other educational technology and distance learning journals.

4. Conclusions

Mapping the research themes and topics featured in four decades of *Computers & Education* shows that the articles progressed through four broad content areas: the advancement and growth of computer-based instruction (1976–1986); stand-alone multimedia

learning (1987–1996); networked computers as tools for collaborative learning (1997–2006); and online learning in a digital age (2007–2016). This progression reflects a) the advance from instructional tools that were rudimentary by today's standards and often viewed with scepticism to sophisticated, powerful and networked systems that are widely accepted as greatly expanding access to education and opportunities for communication and collaboration and b) the rise of new theoretical frameworks influencing the use of the technology in teaching and learning.

This study reveals that there can sometimes be a time lag between the release of a new technology and research reports on its application in an educational context. For example, at the time of writing, out of the over 2201 papers published in the last decade, only 54 of the titles and abstracts include the words “mobile learning”. Some topics such as teaching using the virtual world Second Life in the early 2000s have fallen by the wayside. Some were completely unanticipated. When the first iPhone was launched in 2007, few predicted today's smart phones or the mobile learning revolution. And most of these technologies were not designed expressly for educational applications, so it took time, money and experimentation to establish how and where they could be most effectively applied and the rate and sustainability of the adoption curve depended upon the capability of the early minority to convert the cautionary majority through their research, advocacy and practice (Rogers, 1995).

It must be acknowledged that this study only maps the structure and progression of research topics in educational technology in a single journal, albeit a leading international publication with a long history of extending understanding and practice in applying digital technology to enhance education. In such a study, there is always the possibility that the use of synonyms and polysemy (multiplicity of meanings in words) may result in a failure to pick up certain items. Also, most of the articles in *Computers & Education* are sourced from the English-speaking world. So further investigations would be needed in comparable journals in the field, as well as books, dissertations and conference proceedings and in languages other than English in order to definitively map and draw conclusions about the research domain of educational technology and establish the connections between the theory, research and practice in the various disciplines and cultures. Furthermore, it would be interesting to investigate how the articles in *Computers & Education* relate to each other and to other journals in the field in terms of citations. Such an analysis would reveal the intellectual structure (see Liu, 2007) of the educational technology research community and to what extent and by what means research reports in one journal influence research methods and findings in other contexts.

On the home page of the journal, the Editors of *Computers & Educati*on state that they “welcome research papers on the pedagogical uses of digital technology, where the focus is broad enough to be of interest to a wider education community” (¶2). The vast majority of the papers in the journal concern applications in schools and higher education. Looking to the future, with the ubiquity of the Internet and mobile devices, increasing use of online and mobile learning in the corporate sector and non-formal education in pursuit of the global 2030 Agenda for Sustainable Development (United Nations, 2015) there are even more great opportunities for researchers to explore the role of educational technology in all aspects of formal and informal education and training across the globe.

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Appendix

A) Distribution of author's country of origin for articles in Computers & Education

Country and region*	Total	%	Cum. %	Country*	Total	%	Cum. %
United States of America	695	18.9	18.9	Argentina	6	.2	97.4
United Kingdom	680	18.5	37.4	Denmark	6	.2	97.6
Taiwan	457	12.4	49.9	Jordan	6	.2	97.8
Spain	172	4.7	54.6	Bahrain	5	.1	97.9
The Netherlands	166	4.5	59.1	Colombia	5	.1	98.0
Canada	162	4.4	63.5	Czech Republic	5	.1	98.2
Australia	132	3.6	67.1	India	5	.1	98.3
Turkey	98	2.7	69.8	Bulgaria	4	.1	98.4
Greece	82	2.2	72.0	Poland	4	.1	98.5
Germany	74	2.0	74.0	Russian Federation	4	.1	98.6
Italy	68	1.9	75.9	Estonia	3	.1	98.7
Republic of Singapore	66	1.8	77.7	Lebanon	3	.1	98.8
Israel	65	1.8	79.4	Nigeria	3	.1	98.9
Belgium	60	1.6	81.1	Qatar	3	.1	99.0
Hong Kong	56	1.5	82.6	Slovenia	3	.1	99.0
China	53	1.4	84.0	Viet Nam	3	.1	99.1
Ireland	50	1.4	85.4	Barbados	2	.1	99.2
Republic of Korea	44	1.2	86.6	Egypt	2	.1	99.2
South Africa	43	1.2	87.8	Ghana	2	.1	99.3

Finland	34	.9	88.7	Iceland	2	.1	99.3
France	34	.9	89.6	Lithuania	2	.1	99.4
Brazil	29	.8	90.4	Luxembourg	2	.1	99.5
Chile	29	.8	91.2	Myanmar	2	.1	99.5
Sweden	29	.8	92.0	Romania	2	.1	99.6
Malaysia	28	.8	92.8	Uruguay	2	.1	99.6
Japan	24	.7	93.4	Brunei Darussalam	1	.0	99.6
New Zealand	22	.6	94.0	Hungary	1	.0	99.7
Norway	21	.6	94.6	Iraq	1	.0	99.7
Portugal	11	.3	94.9	Jamaica	1	.0	99.7
Switzerland	10	.3	95.2	Liechtenstein	1	.0	99.8
Cyprus	9	.2	95.4	Macao	1	.0	99.8
Croatia	9	.2	95.6	Philippines	1	.0	99.8
Mexico	9	.2	95.9	Papua New Guinea	1	.0	99.8
Serbia	9	.2	96.1	Puerto Rico	1	.0	99.9
Iran	8	.2	96.4	Slovakia	1	.0	99.9
Austria	7	.2	96.5	Tunisia	1	.0	99.9
Kuwait	7	.2	96.7	Tanzania	1	.0	99.9
Saudi Arabia	7	.2	96.9	Venezuela	1	.0	100.0
Thailand	7	.2	97.1				

*country of origin of the first author (N = 3672).

B) Frequency of articles authored by male and female researchers by year (N = 3063)

C) The 20 most cited papers in Computers & Education (retrieved in March 2017)

Cites	Author(s)	Year	Title
1434	Sun et al.	2008	What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction
1090	Pelgrum	2001	Obstacles to the integration of ICT in education: results from a worldwide educational assessment
1070	Sharples	2000	The design of personal mobile technologies for lifelong learning
1034	Ainsworth	1999	The functions of multiple representations
998	Papastergiou	2009	Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation
937	Wever et al.	2006	Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review
917	Connolly et al.	2012	A systematic literature review of empirical evidence on computer games and serious games
827	Romero et al.	2008	Data mining in course management systems: Moodle case study and tutorial
826	Motiwalla	2007	Mobile learning: A framework and evaluation
754	Chou & Hsiao	2000	Internet addiction, usage, gratification, and pleasure experience: the Taiwan college students' case

754	Angeli & Valanides	2009	Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK)
730	Rosas et al.	2003	Beyond Nintendo: design and assessment of educational video games for first and second grade students
715	Junco	2012	The relationship between frequency of Facebook use, participation in Facebook activities, and student engagement
712	Selim	2007	Critical success factors for e-learning acceptance: Confirmatory factor models
702	Evans	2008	The effectiveness of m-learning in the form of podcast revision lectures in higher education
679	Koehler et al.	2007	Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology
678	Margaryan et al.	2011	Are digital natives a myth or reality? University students' use of digital technologies
677	Baylor & Ritchie	2002	What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms?
663	Weinberger & Fischer	2006	A framework to analyze argumentative knowledge construction in computer-supported collaborative learning
654	So & Brush	2008	Student perceptions of collaborative learning, social presence and satisfaction in a blended learning environment: Relationships and critical factors

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