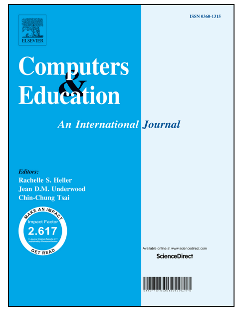

Research on ICT in K-12 schools - a review of experimental and survey-based studies in Computers & Education 2011 to 2015

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Editorial:

Research on ICT in K-12 schools - a review of experimental and survey-based studies in Computers & Education 2011 to 2015

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Editorial: Research on ICT in K-12 schools - a review of experimental and survey-based studies in Computers & Education 2011 to 2015

1. Introduction

What is the role of a journal? Is it to follow the research or lead it? For the former, it is to serve as an archival record of the scholarship in a field. It can serve to permit the research community to engage with each other via the written record. But, for the latter, it can serve the research community by pointing out gaps in the research based on the archival record. This review is intended to do just that.

In recent years there has been an increasing interest in how Information and Communication Technology (ICT) has been used to enhance learning in schools. There are several reasons for this growing interest. Firstly, ICT has the potential to change the nature of disciplines – it changes the sorts of questions you can answer, the ways in which you go about answering them, and the ways in which you represent your understandings. Secondly, ICT provides new ways of supporting learners - it changes pedagogy. Thirdly, ICT opens up access to information, and some claim that it provides opportunities to widen access to education (OECD 2015a, OECD 2015b). Finally, ICT already forms part of the daily lives of children. There is therefore a need to develop learners who can work critically and function in an ICT-rich, connected society.

Many papers have been published by the educational technology research community regarding the needs and effects of using ICT in the classroom (Condie & Munro, 2007; Fu, 2013). Among the reported effects are an improvement in learning and the development of basic, transversal skills or competences. Some of these studies are more teacher-centered, focused on identifying the needs and barriers for ICT adoption at school; others are more student-centered, analyzing the effects that the use of technology has on learner performance. There is consensus among teacher-centered studies that successful implementation of ICT requires the involvement of students, teachers, senior leaders in schools and policy makers as part of the process (Mumtaz, 2000; Ringstaff & Kelley, 2002; Fu, 2013). In terms of educational policies, a recent review, developed by national and local governments of Norway, Flanders and England, analyzed the content features of educational curricula for primary education (Aesaert, Vanderlinde, Tondeur, & van Braak, 2013). The results of the aforementioned review suggest that curricula emphasize the need for developing a critical, safe and responsible use of educational technology. With regards to student-centered studies, the technical report by Condie & Munro (2007) analyzes the results from a literature review of over 350 published articles that reveal the positive impact of ICT use on student performance at school. This study highlights the fact that ICT has the greatest impact on student performance when it is included as a regular part of the classroom experience. Research has also shown that the use of ICT also improves motivation and engagement, resulting in greater persistence and a more profound understanding among students (Underwood, 2009). A positive impact on student performance has also been obtained with particular technologies. This is the case, for instance, of mobile technologies, according to the review by Wu, Jim, Chen, Kao, & Lin (2012).

However, and despite these positive findings regarding the use of ICT in schools reported in the literature, a major review of the impact of ICT in education across phases of education (Luckin, Bligh, Manches, Ainsworth, Crook, & Noss, 2012) found that “evidence of digital technologies producing real transformation in learning and teaching remains elusive” (p.8) and “much existing teaching practice may well not benefit greatly from new technologies” (p.64). This view was supported by a recent analytical report by the OECD (OECD, 2015a) that suggests that the embedding, and thus impact, of technology in education remains sub-optimal. The report by OECD presents a comparative analysis of the digital skills acquired by students in 64 countries (34 OCED countries and 30 partner countries). The main findings are that as currently used in these countries: (1) the use of computers in the classroom is still very low (only 72% of students reported that they use the computer in the classroom); (2) students who report a moderate use of computers at school achieve better learning outcomes than those who use them rarely, but worse than those who use them very often; (3) the use of computers at school does not lead to appreciable improvements in students’ reading, mathematics or science skills; and (4) technology does not help bridge the skills gap between advantaged and disadvantaged students. That is, this report points out that the ways in which ICT has been used so far are not having the expected beneficial impacts. Therefore, there is a need of exploring new approaches in which technology is embedded more effectively in education.

Computers & Education is considered one of the most influential journals in the field of educational technology (Zurita, Merigó, & Lobos-Ossandón, 2015) and is positioned in the top 5% in its category by Thomson Reuters through the Journal Citation Report in both Social Sciences Citation Index (SSCI) and Science Citation Index (SCI). Given the findings reported by the OECD, we contend that the educational technology community has the responsibility to open a debate and a critical discussion about **how we address the study of the impact and adoption of ICT in schools, and how ICT has contributed to improving student learning, competences and skills development**. To this end, this editorial presents a **systematic, quantitative review** (Green, Johnson, & Adams, 2006; Pan, 2008, pp. 1-5) of the studies published in **Computers & Education** over the last five years (**from 2011 to 2015**). Our aim is to learn from the most cited publications and shed light on how future research within the educational technology community should be conducted.

This systematic review of the impact and adoption of ICT in K-12 schools looks to provide an overview of current research in Computers & Education and address the problems reported by the OECD (OECD, 2015a). Specifically, seven research questions (RQ) that arise from the main research objective are addressed in this review:

RQ1. Which papers have been the most cited over the past five years?

RQ2. Where was the research carried out?

RQ3. Which disciplines were addressed?

RQ4. Which levels of education were addressed?

RQ5. Who are the study participants and what are the competences aimed to be improved of these participants?

RQ6. Which methods were used to analyze the impact/adoption of technology in school settings?

RQ7. How was this research funded?

2. Methodology

The methodological approach adopted for this paper consists of a systematic review (Green et al. 2006; Pan, 2008, pp. 1-5). Systematic literature reviews are a form of research that help bring a new perspective to the topic that is reviewed and generate new knowledge (Kitchenham, 2004; Torraco, 2005). Other studies on educational technology have previously used this methodological approach as a framework for organizing a literature review, especially in the field of science education (Gikandi, Morrow, & Davis, 2011; Manathunga & Hernández-Leo, 2015).

The major advantage of the systematic review approach is that "it provides information about the effects of some phenomenon across a wide range of settings and empirical methods" (Kitchenham, 2004 p. 2). In this case, we include publications addressing the problem from the perspectives of the different school stakeholders of how technology has contributed to improving learning. A second advantage is that systematic review has proven to be effective for reviewing, analyzing, critiquing and re-conceptualizing knowledge in mature areas in order to identify gaps in current research and formulate a research agenda that poses new ideas and directions for future investigation in the field.

The systematic review process was articulated following the three steps proposed by Kitchenham (2004): *planning the review*, *conducting the review* and *reporting the review*. The following subsections describe the first two phases of the review, highlighting the importance of this work as well as detailing how the literature review was organized, how the corpus of papers was selected, and the process that was followed by the reviewers. The reporting of the results can be found in section 3.

2.1 Importance of the review

Before carrying out this study, we conducted preliminary research to identify whether a similar literature review on the topics addressed in this paper was already available. For this research, we formulated a search clause in the Scopus database. This database is commonly used in the field of educational technology because it includes the most relevant publications of peer-reviewed scientific journals in this area (considering impact factor), as well as in other related fields such as Social Sciences, Engineering and Computer Science (Falagas, Pitsouni, Malietzis, & Pappas, 2008). The aim of the search clause in Scopus was to detect the main terms related with the research focus, i.e. "review", "school", "K-12", "technology", and "ICT"[1], in the title, abstract and keywords of any paper published since the beginning of 2010. This query did not return any results. The same outcome was obtained when deleting the word "technology" or the word "school" from the search clause. One paper was obtained when deleting the word "ICT", but this paper did not turn out to be representative. Finally, when deleting the word "K-12" from the search clause, the query returned 62 papers. However, of these, the only papers that actually consisted of a review were either focused on a particular region (e.g., Hong Kong (Lam & Woodhead, 2012), China, USA (Alamin, Shaoquing, & Le, 2015), South Africa (Goosen & Van Der Merwe, 2015), etc.), or on a particular area of knowledge (language learning (Yang, H., 2012), music education (Southcott, & Crawford, 2011), etc.). These papers therefore do not offer a broad perspective of how ICT is employed in K-12 schools, thus justifying the need for this review.

2.2 Planning the review: organization of the systematic review

2.2.1. Paper Selection

The initial step before conducting the review consisted of selecting the corpus of papers for subsequent analysis. Since the aim of the paper is to point out gaps in the research on the impact of ICT in K-12 schools to capture somehow what is currently happening in the educational technology community, we considered papers published in Computers & Education over the last five years, from the beginning of 2011 to the end of 2015. Scopus was selected as the database for conducting the filtering process. Although we could have used the Science Direct database, which is directly linked from Computers & Education, we preferred using Scopus for two reasons. Firstly, Scopus includes features for generating advanced queries and saving them. This facilitated the process of filtering the corpus of papers related with the impact and adoption of ICT in K-12 schools from among all of the papers published in Computers & Education between 2011 and 2015. Secondly, this database also offers features for exporting the results from searches as spreadsheets, thus facilitating any subsequent analysis.

[1] Query: TITLE-ABS-KEY (school, K-12, technology, review, ICT) AND PUBYEAR > 2010

The specific key words used for the filtering process were “school” OR “K-12” OR “classroom”, and the search included titles, abstracts and keywords[2]. The aim of choosing “school” as a key word was to include any papers where research was conducted in secondary school, primary school and/or pre-school. The term “K-12” was used so as to include any studies using the American nomenclature. Finally, “classroom” was chosen in order to include any papers that do not specify the learning setting, but where technology is used in school.

Computers & Education published 1,216 papers between January 2011 (volume 65) and December 2015 (volume 90)[3]. These 1,216 papers were filtered using the Scopus database and the keywords mentioned above. The result was a pool of 511 papers, which were defined as the corpus of analysis. From this pool, 352 papers were selected[4] and 159 papers were excluded because of a lack of experimental validation in their methods, or because the sample of the study was not in K-12 education (Table 1). Exceptions to the latter were studies reporting results on pre-service teacher education. As pre-service teachers are the future of ICT use in K-12 schools, these studies were therefore included in the analysis, considering the teachers as study participants. It is important to note that this study is focused on experimental and survey-based studies and does not consider research that is exploratory (finding out what is happening and why – with no intervention, other than the researcher’s presence/data collection).

Table 1 Results from the selection process

Selection results	**No of papers**
Included	352
Excluded (No experimental validation)	17
Excluded (Participants over 18 years old)	142
Papers on the corpus of analysis	511

2.2.2 Mapping the research questions onto the data

Each of the research questions was matched to one or more categories for conducting the systematic review. Table 2 shows the complete list of research questions that were addressed and a description of the analytical categories that were defined.

2 Query: "(SRCTITLE(computers and education) AND TITLE-ABS-KEY(school) OR TITLE-ABS-KEY(K-12) OR TITLE-ABS-KEY(classroom)) AND DOCTYPE(ar) AND PUBYEAR > 2010 AND PUBYEAR < 2016 AND (LIMIT-TO(EXACTSRCTITLE,"Computers and Education"))"
3 Query: (SRCTITLE(computers and education) AND PUBYEAR > 2010 AND PUBYEAR < 2016 AND (LIMIT-TO(EXACTSRCTITLE,"Computers and Education"))"
4 Pool of papers (N=352) considered in this study:
https://docs.google.com/spreadsheets/d/1OZ3uCOt9li08_zeE_aekqj3su_8wWbaV_049h6Wod1I/edit?usp=sharing

Table 2 List of research questions and associated categories for the analysis.

Research question (RQ)	Categories (C)
RQ1. Which papers have been the most cited over the past five years?	(C1a) Number of Citations in Scopus; (C1b) Number of Citations in Google Scholar.
RQ2. Where was the research carried out?	(C2) Corresponding author affiliation: *Africa, Asia, Eastern Europe, Latin America & Caribbean, Middle East, North America, Oceania and Western Europe*.
RQ3. Which disciplines were addressed?*	(C3) Disciplines based on a modified version of the taxonomy of knowledge domains adopted in Wu et al. (2012): *Humanities; Social Sciences*; *Natural Sciences; Formal Sciences*, which includes *Mathematics*, *Teaching Computer Science*, and *Robotics*; *Professions and Applied Sciences*, which include Education, Engineering, Health Sciences and Law, and *Transversal* (cross-disciplinary studies or studies addressing 21st century competencies, such as collaboration, communication, etc.).
RQ4. Which levels of education were addressed?	(C4) Education level defined according to the 2nd stage organization mechanism: *Pre-school* (4 years or under), *Primary* (5-11 years old), *Secondary* (12-18 years old) and *School in General* (when the age of the children is not specified).
RQ5. Who are the study participants and what are the competences aimed to be improved of these participants?	(C5a) Main study participants, which can be teachers, students, parents or administrators/head teachers; (C5b) Main focus of the research, an open space in which to write the paper's topic of study. This last category is proposed to identify the competences aimed to be improved/analyzed on the participants in the study.
RQ6. Which methods were used to analyze the impact/adoption of technology in school settings?*	(C6a) The data gathering techniques (*quantitative*, *qualitative*, *mixed*); (C6b) Participants, distinguishing between studies that involve study participants in the design of the solution from those that do not; (C6c) Period during which the intervention is applied; i.e. period in which the experiment takes place; and (C6d) Number of participants in the experiment.
RQ7. How was this research funded?	(C7) Funding source according to the acknowledgments included in the paper, distinguishing between *private*, *public* or *local funding* (i.e. when the funds come from the institution carrying out the research).

*More information on these categories is included in the results section (Section 3).

2.3. Conducting the review: a three-phase approach

In **Phase 1** three researchers, experts in the area of Technology Enhanced Learning participated in an **initial review process**. The reviewers classified and coded the papers according to the categories defined in Table 2, analyzing only the title, keywords and abstract of the papers. This process was carried out using a shared Google Spreadsheet[5]. This Google Spreadsheet was configured as a concept matrix including the different categories (the main units of analysis) in order to synthesize the analysis (Webster &

Watson, 2002). For some units, this matrix also included a list of proposed attributes in order to ensure the consistency of the analysis. For example, for the category *(C2) Corresponding affiliation of the main author* there was a drop-down menu to indicate the region of the main author (Africa, Asia, Eastern Europe, Latin America & Caribbean, Middle East, North America, Oceania and Western Europe). The 352 papers were distributed among the three researchers. In a second round, the researchers reviewed the papers analyzed by others so as to guarantee consistency and agree on their categorization, especially for papers tagged as “not clear” by the first reviewer.

After this first phase, we detected that some relevant information was not contained in the title, keywords or abstract of the papers. For example, some papers did not include information about the number of participants involved in the experimental design. Others did not specify the research design, while none of them referred to the funding sources in the abstract.

In **Phase 2**, the attributes missing from the first round were completed. A fourth researcher was invited to participate in this phase. This researcher reviewed all the papers, analyzing both the methodology and acknowledgement sections in order to complete the attributes related to categories C6a, C6b, C6c, C6d, and C7 (Table 2). Subsequently, two of the researchers that participated in the first phase reviewed any papers in which this information was not clearly stated so as to contrast the analysis and discuss their final decision, thus guaranteeing consistency.

In **Phase 3**, the resulting spreadsheet was analyzed using the statistical software tool StataIC 14 to evaluate the integrity of the data that was extracted. The results from the paper categorization were tabulated in order to detect any repetitions and ensure that the information was complete. In this phase, incomplete attributes were detected, as well as inconsistencies between words with the same meaning but written differently (e.g. “behavior” or “behaviour”).

Following this three-phase process ensures both the reliability and the validity of the review (Read, 2013). The analysis of a large number of published papers ensures the reliability of the process, as well as the consistency of the conclusions. The corpus of analysis (352 papers) represents a significant population of published studies. Additionally, papers were also selected from one of the most cited journals in the field of educational technology, which ensures that certain quality standards are met. Furthermore, two mechanisms were used to ensure the internal and external validity of the analysis. Firstly, four researchers cross-analyzed the papers that were selected by reviewing and discussing the categories assigned to each paper from different perspectives. Secondly, a systematic procedure was used for selecting papers, thus ensuring the validity of this study.

3. Reporting the review: descriptive results and discussion

RQ1: Which papers have been the most cited over the past five years? Scopus & Google Scholar Citations

Error! Reference source not found. shows the number of publications selected for each year, and the range of citations according to Scopus and Google Scholar. Since Google Scholar not only includes citations in scientific publications but also in dissertations, books, pre-prints, and technical reports, among others, the number of citations per paper is greater than or equal to those in Scopus. In order to determine the most cited papers, we identified the papers that were responsible for 50% of the citations in both the Google Scholar and Scopus, from among the selected pool of papers. In this sense, 50% of citations were concentrated among 15.45% of the papers, i.e. 54 of 352 papers. These 54 papers are taken as the list of the most cited papers. Moreover, and as shown in Figure 1, most publications are distributed in the lowest number of citations according to both Scopus and Google Scholar. The most cited papers considered in this study are listed according to their number of citations in Annex I. **Error! Reference source not found.** describes the results obtained from the analysis of all the selected papers (N=352), and compares them with the results of running the same analysis with the most cited papers (N=54).

We select the most cited papers as a measure to understand the impact of the research analyzed, however this method has some limitations. Firstly, there is a long time lag between a paper being published and citations appearing, so more recent papers will inevitable have fewer citations. Secondly, citations indicate that the paper has been referenced elsewhere but tells you nothing about the nature of the reference – so, for example, the referring paper may be critiquing the referenced paper (which would suggest that that citation was not an indicator of influence).

Table 3 Description of the papers included in this review

	2011	2012	2013	2014	2015
All papers included in the review (N=352)					
Number of papers	76	61	73	71	72
Range of Google Scholar citations per paper (max-min)	139-2	86-1	96-0	29-0	7-0
Range of Scopus citations per paper (max-min)	63-0	44-0	46-0	17-0	4-0
Average citations per year in Google Scholar	40.69	29.59	20.00	8.5	1.55
Average citations per year in Scopus	18.76	12.06	8.50	3.49	0.46
Most cited papers (N=54)					
Number of papers	29	17	8	0	0

Range of Google Scholar citations per paper (max-min)	139-31	86-38	96-42	-	-
Range of Scopus citations per paper (max-min)	63-14	44-10	46-14	-	-
Average citations per year in Google Scholar	73.45	59.90	61.10	-	-
Average citations per year in Scopus	33.66	25.70	25.60	-	-

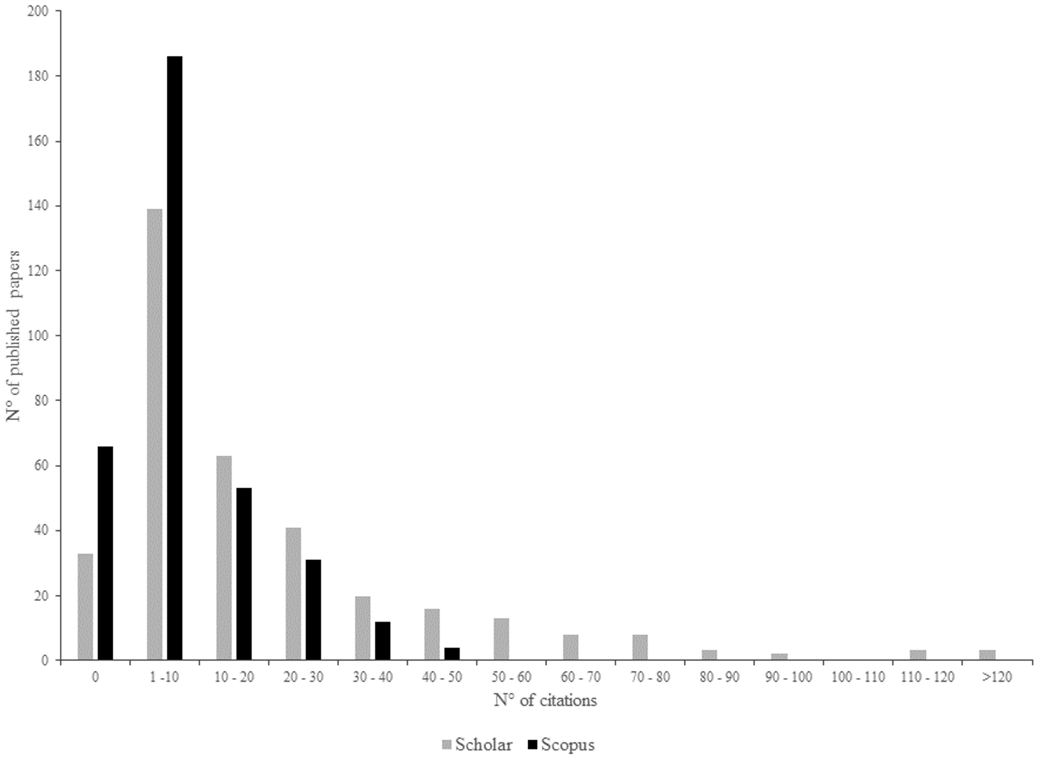

Figure 1 Histogram of the papers according to the number of citations in both Scopus and Google Scholar. The figure shows that most publications are distributed in the lowest number of citations and that only a few papers accumulate most of the citations.

RQ2: Where was the research carried out? Corresponding author affiliation

The region of the corresponding author affiliation was analyzed to identify where the selected studies were conducted. Although the author affiliation does not necessarily indicate the country where the study was conducted, it is an indicator of the investment that different countries make on this type of research. Table shows the eight different regions that were considered in the study. The most productive region in terms of numbers of papers published is Asia, with 33% (N=117) of all the selected papers, followed by Western Europe (23%; N=82) and North America (21%; N=72). Thus, three regions of the world produced more than 75% of the published research regarding the use of ICT in K-12 schools. When analyzing the most cited papers, we observe that this percentage increases to 83%. It is worth noting that most of the research in the field cannot be generalized for underrepresented regions, such as Africa, Eastern Europe, Latin America, Middle East or Oceania. In the breakdown by regions, it is worth noting that 73 of 117 (62%) of Asian papers are from Taiwan. In Western Europe, from the 82 papers, the leading countries are

United Kingdom (N=15), Belgium (N=14), and the Netherlands (N=14). Finally in North America, United States is the leader of the research with 92% of the papers published in the region (N=66).

Table 4 Number of published papers per region according to corresponding author affiliation

	All papers included in the review		**Most cited papers**	
Region	**No. of papers**	**%**	**No. of papers**	**%**
Africa	2	1%	1	2%
Asia	117	33%	21	39%
Eastern Europe	18	5%	2	4%
Western Europe	82	23%	12	22%
Latin America & Caribbean	18	5%	3	5%
Middle East	30	8%	1	2%
North America	72	21%	12	22%
Oceania	13	4%	2	4%
Total	**352**	**100%**	**54**	**100%**

RQ3: Which disciplines were addressed?

Table 5 shows the disciplines in which the studies were conducted; that is, the knowledge area of the course or educational event in which the study takes place. In some cases, what the authors of the study want to achieve or improve is related with the discipline, but in some cases it is not (i.e. the study takes place in a course on Calculus – the discipline would be Mathematics –, but the authors aim is to improve students' collaboration skills – which in this study would correspond to the 'Transversal' category (see below)). Table 5 also indicates the number of papers in each discipline. Six disciplines were considered in the analysis based on a modified version of the taxonomy adopted in Wu et al. (2012):

(1) Humanities, which include history, language and linguistics, literature, arts, etc.;

(2) Social Sciences, which include economics, sociology, gender studies, etc.;

(3) Natural Sciences, which include chemistry, physics, life sciences, etc.;

(4) Formal Sciences, which include (4a) Mathematics, (4b) Computer Sciences, and (4c) Robotics. Although Wu et al (2012) included Mathematics, Computer Sciences and Robotics within a common category; we treated them as three discrete categories because these were categories employed in several of the papers analyzed.

(5) Professions and Applied Sciences, which include education, engineering, health sciences, law, etc.

(6) A new category which we labeled as "Transversal" to refer to: (1) cross-disciplinary studies, intervening or taking place in more than one discipline; and (2) studies focusing mainly on the development of transversal skills or competences such as collaboration, critical thinking, etc. It also includes those papers that analyze how ICT is used in an educational context for professional or administrative purposes.

Table 5 Number of published papers per discipline

	All papers included in the review		Most cited papers	
Discipline	**No. of papers**	**%**	**No. of papers**	**%**
Humanities	55	15%	11	20%
Social Sciences	6	2%	1	2%
Natural Sciences	58	16%	19	35%
Formal Sciences (Total)	53	16%	4	8%
Mathematics	30	9%	2	4%
Computer Sciences	21	6%	2	4%
Robotics	2	1%	0	0%
Professions and Applied Sciences	22	6%	3	5%
Transversal	158	45%	16	30%
Total	**352**	**100%**	**54**	**100%**

The studies in most of the selected papers are not directly related to a particular discipline; rather they are cross-disciplinary studies, intervening or taking place in more than one discipline (45% classified as Transversal; N=158). This trend is followed by 16% (N=58) of selected papers addressing Natural Sciences, 15% (N=55) focusing on Humanities, and 9% (N=30) on Mathematics. Interestingly, Table 5 reveals that among the most cited papers, the most popular discipline was Natural sciences (35%; N=19), followed by Transversal skills (30%, N=16).

PISA assesses Humanities, Natural Sciences and Mathematics and, since 2015, transversal skills as well, such as collaboration (De Jong, 2012). Conversely, our review shows that most of the articles published in Computers & Education report mainly on transversal disciplines but not on the specific disciplines assessed by PISA. Another interesting finding is that Mathematics is represented in a smaller proportion of published papers compared to Humanities and Natural Sciences. This could be due to a limitation of our study, as we are only considering papers published in the Computers & Education journal, although there are other quality journal publications in mathematics teaching that we are not taking into consideration. Moreover, when analyzing the most cited papers, the proportion of papers focusing on Language and Natural Sciences increases significantly, while the proportion of papers focusing on Mathematics halves.

RQ4: Which levels of education were addressed? Levels of education

The following levels of education were considered in this category: pre-school, for interventions with children aged 4 or under; primary, for interventions with children aged between 5 and 11; secondary, for interventions with children aged between 12 and 18; and school, for interventions with school children where the age is not explicitly indicated.

Additional categories were also included where there was a combination of levels that were addressed simultaneously in the papers that were analyzed: pre-school + primary, and primary + secondary.
Table shows that 165 of the selected articles focus on Secondary education (46%; N=165), of which 145 looked exclusively at Secondary education. 40% (N=141) of the papers focus on studies conducted at Primary level, of which 119 are focused solely on Primary education. In terms of the most cited papers,
Table shows that the most relevant papers are those that focus on one single level of education.

Table 6 Number of published papers per Level of Education

	All papers included in the review		Most cited papers	
Level of Education	**No. of papers**	**%**	**No. of papers**	**%**
Pre-school	10	3%	1	2%
Pre-school + Primary	2	1%	0	0%
Primary	119	34%	21	39%
Primary + Secondary	20	5%	0	0%
Secondary	145	41%	22	41%
School (unspecified)	56	16%	10	19%
Total	**352**	**100%**	**54**	**100%**

Finally, Table 7 shows the cross-analysis of the levels of education with disciplines (RQ3). We identified that most of the papers classified as Transversal intervene in Secondary education (74 papers, from which 57 are solely of Secondary Education), Primary education (67 papers, from which 50 are solely of Primary Education), or School in general (27 papers). Only 7 papers classified as Transversal are aimed at a pre-school level (Table). In addition, we observe that most of the papers classified on the Computer Sciences section intervene mostly in Secondary education (11 papers, from which 10 papers are solely of Secondary Education), followed by Primary education (2 Pre-school + Primary and 6 Primary).

Table 7 Number of papers per Level of Education and Disciplines

Level of Education	Human -ities	Social Sci.	Natural Sci.	Professions & Applied Sci.	Formal Sciences			Trans versal
					Math	Computer Sci.	Robotics	
Pre-school	2	0	0	0	0	0	1	7
Pre-school + Primary	0	0	0	0	0	2	0	0
Primary	27	1	22	4	9	6	0	50
Primary+ Secondary	0	0	2	0	0	1	0	17
Secondary	22	4	28	7	17	10	0	57
School	4	1	6	11	4	2	1	27

RQ5: Who are the study participants and what* are the competences aimed to be improved of these participants*?

Table 8 shows study participants in the research studies (*C5a)*, categorized as: students, teachers, parents and head teachers/administrators. This category was proposed in order to identify the participants that are targeted in each study, that is, whether the focus of the research is to analyze/improve teachers, students, parents or administrators/head teachers' competences. In 77% (N=269) of the studies, the participants are the students, of which 240 studies are purely student-centered, without considering any other participants. Although published research stresses the importance of considering how teachers are using ICT in schools and for what purposes (Fu, 2013), only 30% (N=106) of the studies consider teachers as part of study participants or study sample (this includes Teachers Solely, and all possible combinations of teachers plus any other participant). Of this latter group, only 76 papers are purely teacher-centered. Figure 2 shows the evolution of the predominant study participants (teacher- and student-centered) over time.

Table 8 Number of published papers per study participants

	All papers included in the review		**Most cited papers**	
Study participants	**# of papers**	**%**	**# of papers**	**%**
Students	240	68%	35	65%
Teachers	76	21%	15	28%
Parents	3	1%	1	2%
Head Teachers / Administrators	3	1%	0	0%
Teachers + Students	21	6%	3	5%
Teachers + Administrators	1	0%	0	0%
Teachers + Students + Parents	2	1%	0	0%
Teachers + Students + Head Teachers/Administrators	4	1%	0	0%
Teachers + Students + Head Teachers/Administrators + Parents	2	1%	0	0%
Total	**352**	**100%**	**54**	**100%**

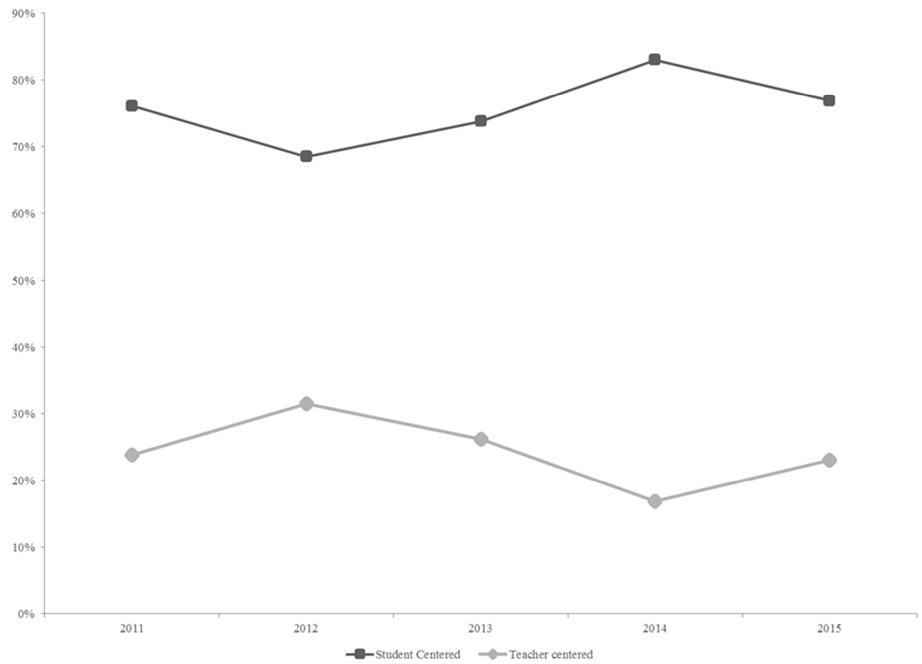

Figure 2 Proportion of papers published per year according to predominant study participants within the corpus (teacher- and student-centered papers).

We also examined the main research focus (*C5b*) of the selected studies, which was classified according to the topics presented in Table 9. In contrast to the disciplines, the focus of these cases was on participants' specific competences that the research aimed to enhance rather than on particular disciplines. These categories were not defined from the beginning; instead they emerged throughout the review process and were added to the analysis when they were addressed by at least three papers. Any category covered by only one or two papers is included under "other". Table 9 shows that 39% (N= 127) of the papers focus on studying how to improve competences identified as 21st century skills (Finegold & Notabartolo, 2010), with 12% (N=43) of the papers addressing ICT operations and concepts (aspects that have to do with the operation of ICT (using a program, for example) and concepts such as network, internet, etc.). When examining the most cited papers, the results show that 17% (N=9) of the papers address the interaction of study participants (both, teachers and students) with technology; i.e., analyzing user interface interactions, logfiles with the systems, etc. The most cited papers are followed by those that explore how to improve learning in a particular topic or area (13%; N=7), as well as those that address motivation (13%; N=7).

Our review reveals that 17% of the papers focus on analyzing/improving participants' learning outcomes, 13% of the papers analyze the interaction of the participants with a particular technology/tool, and 12% focus on analyzing/improving competences related with ICT operations and concepts. In addition, we observe that most of the articles included in this systematic review explore transversal knowledge and abilities, such as the so-called 21st century skills.

With regards to the development of 21st century skills, experts considered the possibility of reformulating the PISA instrument in order to include them (De Jong, 2012). The assessment of problem solving and financial skills was already included in 2012, and collaborative problem solving was incorporated in 2015. Research that is published on transversal skills should therefore inform these ongoing discussions about the PISA programme and further work on student assessment. These results suggest that there is a lot of research within the community that aims to improve transversal skills. This might have a positive effect on future PISA examinations that include assessment of such skills.

Table 9 Research aim of papers included in the review

	All papers included in the review		**Most cited papers of those included in the review**	
Research aim	**No. of papers**	**%**	**No. of papers**	**%**
21st Century Skills				
ICT Operations and concepts	43	12%	6	11%
Creativity/Innovation	4	1%	0	0%
Critical Thinking	22	6%	3	5%
Problem solving	7	2%	3	5%
Collaboration	24	7%	4	7%
Information Literacy	13	4%	0	0%
Flexibility and adaptability	2	1%	0	0%
Initiative and self-direction	11	3%	1	2%
Productivity	1	0%	0	0%
Leadership and responsibility	9	3%	0	0%
Other				
Assessment	24	7%	3	6%
Beliefs	21	6%	6	11%
Disabilities	4	1%	1	2%
Inequalities	4	1%	0	0%
Interaction	47	13%	9	17%
Learning	61	17%	7	13%
Motivation	23	7%	7	13%
Orchestration	4	1%	1	2%
TPACK/TPCK Instruments	7	2%	2	4%
Other	21	6%	1	2%
Total	**352**	**100%**	**54**	**100%**

By cross-analyzing the papers that address the most frequent Research Aims with Disciplines (RQ3) (Table 10), we identified that 31 of 40 papers that studied ICT operations and interaction are focused on improving or analyzing Transversal Skills, while studies about learning are focused on a particular discipline (N=61) and papers about motivation (N=23) are mainly focused on Humanities or Transversal Skills.

Table 10 Disciplines of papers focused on ICT Operations and Concepts, interaction, learning and motivation

Most frequent research aim	Human -ities	Social Sci.	Natural Sci.	Professions & Applied Sci.	Formal Sciences			Trans versal
					Math	Computer Sci.	Roboti cs	
ICT Operations and Concepts	2	1	2	1	1	2	0	31
Interaction	8	1	7	1	4	1	0	25
Learning	10	2	17	6	10	5	1	10
Motivation	8	0	1	2	2	1	1	8

RQ6: Methods used

We analyzed four aspects related to the methods used in the studies (Tables 11-17). Firstly we looked at the nature of the data collected (C6a). Given that our criteria for selecting papers all of the studies that we analyzed were coming from an objectivist stance. Within this overarching objectivist framework, the studies did vary in the data gathering techniques. We have categorized these as Quantitative, Qualitative and Mixed. The results in Table 11 show that most of the papers collected quantitative data (50%; N=176), followed by a mixture of quantitative and qualitative data (34%; N=121).

Table 11 Data collected within the papers included in the review

Research method	All papers included in the review		Most cited papers of those included in the review	
	No. of papers	**%**	**No. of papers**	**%**
Mixed	121	34%	17	31%
Qualitative	55	16%	8	15%
Quantitative	176	50%	29	54%
Total	**352**	**100%**	**54**	**100%**

The second aspect that was analyzed was the involvement of participants in the study (*C6b*). Since this study only focus on experimental and survey-based studies and does not considers exploratory research (research conducted to understand a problem that is not clearly defined), we categorize the papers between studies where the technological intervention or solution that is proposed is co-designed or considers the feedback or needs of study participants and those where it does not. We considered the former as any paper where the research method that is followed "*pulls* information from the user to build up the solution". The Design-Based Research methodology (Wan & Hannafin, 2005) is one example of such a method. When the research method does not take into consideration the study participants in the design of the solution, they are "*pushing*" the solution. When the focus of the analysis is an instrument for assessing a particular skill or competence, we classify this as "Not applicable" (Table 12). In terms of the involvement of participants, Table 12 shows that most of the research that is conducted does not consider the study participants in the solution that is proposed. Only 24% (N=85) of the studies considered the study participants in the solution proposed by the paper. For example, 4 papers in the latter group followed a Design-Based Research approach.

Table 12 Research method adopted by all of the papers included in the review

	All papers included in the review		**Most cited papers of those included in the review**	
Research method	**No. of papers**	**%**	**No. of papers**	**%**
Not applicable	38	11%	8	15%
Does not consider the study participants in the solution	229	65%	34	63%
Considers the study participants in the solution	85	24%	12	22%
Total	**352**	**100 %**	**54**	**100%**

The third aspect that was analyzed was the period across which the data were collected (*C6c*) (see Table 13). In this case, we distinguish between short-term interventions (less than five weeks or 5 sessions), middle-term interventions (between 5 and 12 weeks or sessions) and long-term interventions (more than 12 weeks or 12 sessions). The distinction between middle-term and long-term was defined by considering the number of weeks in a typical school term. Additionally, we classified any paper that analyzed data captured in a single intervention or existing data that did not require further data collection (e.g. validating a survey instrument) as "Not applicable". If no information was given regarding the number of sessions or weeks for the study undertaken, the paper was classified as "No information". Table 13 reveals that 21% (N=75) of the papers propose long-term interventions, followed by 14% (N=50) that propose middle-term interventions, and short-term with the 9% of the papers (N=31). In the case of the most cited papers, there is a significant increase in the percentage of short-term interventions, 15% (N=8).

Table 13 Intervention period used for the studies included in the review.

	All papers included in the review		**Most cited papers of those included in the review**	
Intervention period	**No. of papers**	**%**	**No. of papers**	**%**
Short-term	31	9%	8	15%
Middle-term	50	14%	6	11%
Long-term	75	21%	9	17%
Not applicable/No Information	196	56%	31	57%

Total	**352**	**100%**	**54**	**100%**

The last aspect that was analyzed was the number of participants in the study (*C6d*) (See Table 14). Table 14 shows that 9% (N=31) of the papers proposed studies involving between 1 and 20 participants, followed by 36% (N=126) that involve between 20-100 participants, and 21% (N=76) of the studies that involve between 100 and 250 participants. Only 9% (N=30) of the studies involve between 500-1000 participants. Furthermore, we see that 48% (N=26) of the most cited studies involve between 1 and 100 participants, and 24% (N=13) between 100 and 250.

Table 14 Range of participants in the papers included in the review.

	All papers included in the review		**Most cited papers of those included in the review**	
Range of participants	**No. of papers**	**%**	**No. of papers**	**%**
1-20	31	9%	5	9%
20-100	126	36%	21	39%
100-250	76	21%	13	24%
250-500	42	12%	3	6%
500-1000	30	9%	6	11%
>1000	47	13%	6	11%
Total	**352**	**100%**	**54**	**100%**

Finally, we conducted a cross-analysis of some of the variables (Tables 15, 16 and 17). In Table 15 we can observe that the pattern for the number of participants involved differs for studies using quantitative data, where 54 out of 176 papers involve less than a hundred participants, and 62 involve between 100 and 500 participants.

Table 15 Comparison of sample size against research method (excluding papers involving other combinations and those with no information regarding the level of education)

	Sample size						
Research Method	**0-20**	**20-100**	**100-250**	**250-500**	**500-1000**	**>1000**	**Total**
Mixed	4	55	33	14	6	9	121
Qualitative	24	20	6	3	1	1	55
Quantitative	3	51	37	25	23	37	176

When cross-analyzing the periods of intervention in relation to the Level of Education (Table 16), we observe that 31 of the 75 long-term studies take place specifically in Primary (N=32), and 26 are solely focused on Secondary education. This distribution between Primary and Secondary education changes for middle-term studies considering that the number of papers focused on Secondary is higher, and this difference between the two educational levels is not observed in short-term studies.

Table 16 Comparison of intervention period with the Level of Education (excluding papers involving other combinations and those with no available information regarding the level of education)

	Level of Education						
Intervention Period	**Preschool**	**Preschool +Primary**	**Primary**	**Primary +Secondary**	**Secondary**	**School**	**Total**
Long-term	0	1	31	2	26	15	75
Middle-term	3	0	17	2	23	5	50
Short-term	1	0	12		13	5	31
Not applicable/No information	6	1	59	16	83	31	196

Finally, Table 17 shows that most long-term studies focus on Humanities (N=22), followed by Transversal disciplines (N=20) and Natural Sciences (N=12). Middle-term studies focus on the same disciplines but in a different order, prioritizing Transversal knowledge (N=15), then Humanities (N=6), Natural Sciences (N=6) and Math (N=6). Finally, short-term studies focus mostly on Humanities (N=9), Transversal knowledge (N=8), and Natural Sciences (N=8).

Table 17 Comparison of Intervention period with disciplines

Intervention period	**Hum.**	**Social Sci.**	**Natural Sci.**	**Prof. and Applied Sciences**	**Math**	**C. Sci.**	**Rob.**	**Transv.**	**Total**
Long-term	22	2	12	4	10	5	0	20	75
Middle-term	8	0	6	6	6	7	2	15	50
Short-term	9	0	8	2	2	2	0	8	31
Not applicable/No information	16	4	32	10	12	7	0	115	196

RQ7: Funding Source.

This category was analyzed to understand how research in this area is funded. We organized the funding sources into three groups: private sources (e.g., companies or private foundations); public sources (regional, national or international programs); and local sources (e.g., the institution/s where the authors of the paper work).

Table 18 shows that most of the funding in the papers selected in this review come from local (48%, N=167) and public sources (39%, N=138). Only 6% (N=22) of the funding comes from private sources.

Table 18 Type of funding for the papers included in the review

	All papers included in the review		Most cited papers	
Research design	**No. of papers**	**%**	**No. of papers**	**%**
Local funding	167	48%	26	48%
Private	22	6%	1	2%
Public	138	39%	23	43%
Mixed	25	7%	4	7%
Total	**352**	**100%**	**54**	**100%**

4. Conclusions and limitations of the study

Considering that the OECD found in a recent report (OECDa, 2015) that the embedding, and thus impact, of technology in education remains sub-optimal, our aim was to learn from the experimental studies published in Computers & Education over the last five years, and determine how we can conduct research that is more relevant to the education community.

Although mechanisms were used in order to ensure the consistency and the validity of the results that were obtained, there are certain limitations that restrict our findings. Firstly, restricting the analysis to papers published in Computers & Education is one of the study's limitations. Including more journals and research sources would have meant having a bigger corpus of papers for analysis and, therefore, a broader perspective on how the pedagogical use of ICT has been addressed in education. Secondly, the selection process also implies certain limitations. On the one hand, when using particular search criteria we may be dismissing some papers that might usefully have informed the literature review, including all 17 of papers that adopted a qualitative approach. In addition, scientific papers always involve some level of bias, since most papers report only positive results (Matosin, Frank, Engel, Lum, & Newell, 2014).

Regardless of the limitations mentioned above, we accomplished our aim by identifying key gaps in the literature. Understanding these gaps may enhance the relevance of research among the education community in the future. The key gaps are as follows:

1) **There is a preponderance of quantitative research within Computers & Education.** Only 55 of the 352 papers about ICT in schools published in Computers & Education between 2011 and 2015 inclusive adopted a qualitative approach (Section 3, RQ6). We need to redress the balance between quantitative and qualitative research, and to that end we will be publishing another editorial in the near future that provides guidance on reporting high quality qualitative research.
2) **More research is needed from different regions for a better understanding of the global use of technology at school level**. Currently, most of the studies are carried out in North America, Western Europe and Asia, disregarding South America, Africa, Oceania and Eastern Europe (Section 3, RQ2). It is important to

notice that context matters. Making direct comparisons across cultures is problematic and thus we need to broaden the cultural contexts within which research on educational technology is conducted

3) **More research is needed in the areas of humanities, natural sciences and formal sciences, especially in mathematics**. The results of this review reveal that most of the articles that were analyzed do not report on the specific disciplines defined by PISA; rather they address transversal disciplines (Section 3, RQ3). Interestingly, many researchers focus on the improvement of 21st Century skills. We need more research about how to assess the skills that we think are important in education (such as 21st century skills), because unless schools are held accountable against those skills they are not likely to teach them. Our research should be enhancing education so that it is fit for our changing world, not reinforcing historical practices in order to address the gaps that, according by the OECD (OECD, 2015b), are not being bridged by current educational systems.
4) **There are very few pre-school studies regarding educational technology in order to explore ICT's effects in early childhood** (Section 3, RQ4). Despite this low number of papers, research has shown the importance of pre-school years in the cumulative learning process of a child (Barnett & Yarosz, 2004).
5) **Studies that ignore what teachers do (how ICT is embedded in practice) are unlikely to be of much value.** Most studies are student-centered (Section 3, RQ5). However, only few focus on understanding how ICT is being used and embedded within the curriculum and teachers' pedagogy. The results of our study reveal that most of the papers are student-centered, disregarding the teacher's perspective (Section 3, RQ5). However, involving the teacher is key for ensuring the positive effects that come from students using technology (Darling-Hammond et al., 2015).
6) **A small proportion of studies involve study participants in their design (and/or the design of solutions)** (Section 3, RQ6). A lack of involvement of key stakeholders in the design of technological solutions may result in a lack of alignment with learners' and practitioners' daily problems or circumstances, limiting the impact of the interventions (Cober et al., 2015).
7) **Where researchers are working within an objectivist approach they should increase the sample sizes and the period over which data are collected.** The results of this study show that, although the number of quantitative studies is high, most of them carry out experiments or quasi-experiments involving fewer than 100 participants (Section 3, RQ6). Less than 50% of the papers involve studies based on data collection over more than twelve weeks. For being generazible the sample has to be representative (López et al., 2015)
8) **Local or public institutions provide most of the funding for the research published in the papers selected in this review.** This results suggests that current research is mainly conducted by scholarly, and that the private sector is not publishing in the channels (Section 3, RQ7).

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ANNEX

Table A1. Papers IDs that accumulate the 50% of the citations in both databases Google Scholar and Scopus. The full list of papers considered in the review is available at the following link: https://docs.google.com/spreadsheets/d/1OZ3uCOt9li08_zeE_aekqj3su_8wWbaV_049h6Wod1I/edit

#	Article Title	Num. of citations in Google Scholar	Num. of citations in Scopus
1	Modeling primary school pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) for meaningful learning with information and communication technology (ICT)	139	63
2	Effects of constructing versus playing an educational game on student motivation and deep learning strategy use	132	62
3	Mobile English learning: An evidence-based study with fifth graders	122	56
4	An interactive concept map approach to supporting mobile learning activities for natural science courses	113	56
5	A knowledge acquisition approach to developing Mindtools for organizing and sharing differentiating knowledge in a ubiquitous learning environment	76	48
6	A case study of the in-class use of a video game for teaching high school history	117	47
7	Factors influencing teachers' intention to use technology: Model development and test	113	46
8	A collaborative game-based learning approach to improving students' learning performance in science courses	82	46
9	An online game approach for improving students' learning performance in web-based problem-solving activities	86	44
10	Learning in a u-Museum: Developing a context-aware ubiquitous learning environment	82	43
11	"Games are made for fun": Lessons on the effects of concept maps in the classroom use of computer games	77	43
12	Teachers and game-based learning: Improving understanding of how to increase efficacy of adoption	77	39

13	Effects of teaching and learning styles on students' reflection levels for ubiquitous learning	95	39
14	An alternate reality game for language learning: ARGuing for multilingual motivation	68	35
15	Factors influencing secondary school teachers' adoption of teaching blogs	67	32
16	Enhancing 5th graders' science content knowledge and self-efficacy through game-based learning	63	31
17	Interactive augmented reality system for enhancing library instruction in elementary schools	47	30
18	Learning and motivational impacts of a multimedia science game	62	29
19	Are educational computer micro-games engaging and effective for knowledge acquisition at high-schools? A quasi-experimental study	59	29
20	The student experience of a collaborative e-learning university module	62	29
21	Computer adaptive practice of Maths ability using a new item response model for on the fly ability and difficulty estimation	58	29
22	A framework for the design and integration of collaborative classroom games	55	28
23	Design guidelines for Classroom Multiplayer Presential Games (CMPG)	39	28
24	Using Wiki in teacher education: Impact on knowledge management processes and student satisfaction	56	28
25	Building virtual cities, inspiring intelligent citizens: Digital games for developing students' problem solving and learning motivation	68	27
26	Computer games created by middle school girls: Can they be used to measure understanding of computer science concepts?	58	27
27	Impact of an augmented reality system on students' motivation for a visual art course	96	27

28	Exploring the TPACK of Taiwanese elementary mathematics and science teachers with respect to use of interactive whiteboards	59	26
29	The study on integrating WebQuest with mobile learning for environmental education	63	26
30	Young students using iPads: App design and content influences on their learning pathways	56	26
31	The beliefs behind the teacher that influences their ICT practices	74	25
32	An analysis of the relationship between information and communication technology (ICT) and scientific literacy in Canada and Australia	50	25
33	Factors related to pedagogical beliefs of teachers and technology integration	76	25
34	From Moodle to Facebook: Exploring students' motivation and experiences in online communities	56	25
35	A concept map-embedded educational computer game for improving students' learning performance in natural science courses	54	24
36	Scaffolding strategies for supporting middle school students' online inquiry processes	38	23
37	A framework for teachers' integration of ICT into their classroom practice	77	23
38	Students' views of collaboration and online participation in Knowledge Forum	59	23
39	Assessment of 21st century ICT skills in Chile: Test design and results from high school level students	41	22
40	Parental acceptance of digital game-based learning	48	22
41	E-books effectiveness in promoting phonological awareness and concept about print: A comparison between children at risk for learning disabilities and typically developing kindergarteners	46	22
42	EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips	58	22

43	Developing Web-based assessment strategies for facilitating junior high school students to perform self-regulated learning in an e-Learning environment	31	21
44	Are young generations in secondary school digitally competent? A study on Italian teenagers	62	21
45	Digital storytelling for enhancing student academic achievement, critical thinking.; Learning motivation: A year-long experimental study	73	21
46	A personalized recommendation-based mobile learning approach to improving the reading performance of EFL students	45	21
47	Teachers' acceptance and use of an educational portal	42	21
48	From access to usage: The divide of self-reported digital skills among adolescents	53	20
49	Game-based curriculum and transformational play: Designing to meaningfully positioning person, content, and context	47	19
50	Exploring pre-service teachers' beliefs about using Web 2.0 technologies in K12 classroom	50	19
51	Effective learning in science: The use of personal response systems with a wide range of audiences	52	17
52	Evaluation of learners' attitude toward learning in ARIES augmented reality environments	42	14
53	Exploring the potential of the will, skill, tool model in Ghana: Predicting prospective and practicing teachers' use of technology	44	14
54	Teachers' perceptions of the barriers to technology integration and practices with technology under situated professional development	73	10