Creativity and Emerging Digital Educational Technologies: A Systematic Review

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ABSTRACT
In order to effectively use emerging digital educational technologies educators should reflect on how these technologies influence student learning, including student creativity. Existing research shows that creativity can be supported by emerging technologies, but recent research in this area has not yet been reviewed. The purpose of our systematic review was to identify and synthesize articles in the field of creativity and education concerning the use of emerging digital educational technologies and systems. To this end, we reduce an initial sample of 267 papers to 37 relevant articles. We assess those articles quantitatively and qualitatively to arrive at a clearer understanding of the state of the research. Our analysis reveals a new division between articles focusing on technologies themselves and articles focusing on curriculum developments in technology-related courses. We conclude that research related to educational technology and creativity has been handled with important issues in the field overall, but certain discrimination deserves to be addressed. Notably, we recommend additional research on the impact of technology on creativity in adult education and lifelong learning. Our synthesis will be of interest to both researchers and practitioners in the field of creativity and education, concerning the use of educational technologies and systems.

Keywords: creativity in education, digital educational technologies, systematic review, digital technologies, emerging educational technologies

INTRODUCTION
Educators must keep track of new educational strategies, methods, and applications, as well as new digital technologies for learning and teaching. To plan, design, and develop effective use of digital educational technologies educators must first reflect on the use and integration of these technologies. One important area for reflection is the effect of such technologies on students' creativity which is considered as being one of the most important characteristics of 21st century learners. The relationship between creativity and technology is well known to educators and noteworthy because both technology and creativity in education are complex areas (Mishra & Henriksen, 2018). In the past few years, there has been an increase in studies on creativity supported by digital technologies (Mishra & The Deep-Play Research Group, 2012). It is important for educators to explore the relationship between technology and creativity in order to discover how creativity can be brought into teaching and learning (Mishra, Henriksen & Mehta, 2015, Yalcinalp & Avci Yucel, 2015).

Creativity in education can be regarded as the ability to apply multiple and new strategies (Mayer, 1989) and the process of formulating, revising, or retesting hypotheses to solve a problem (Torrance, 1988) for both individuals and communities. Creativity can be more broadly defined as "the ability to think in different directions, by modifying an original idea with something new and unique that is useful and appropriate to a given situation" (Amabile, 1983). According to Mayer (1989) creativity is the ability to solve problems that one has not previously learned how to solve. Osche (1990, p.2) indicates that creativity involves "bringing something into being that is original (new, unusual, novel, unexpected) and also valuable (useful, good, adaptive, appropriate)". Creativity is a critical skill that helps look at existing problems from a new perspective, see new opportunities and create new ideas. According to Mishra and Henriksen (2018) the three components (Novel, Effective, Whole) provide a framework for defining creativity: i. Novel, an idea or product that was not available before, ii. Effective, useful, logical, understandable idea or product, iii. Whole, aesthetic, elegant and well-crafted idea or product.

Rutland and Barlex's (2008, p.143) definition of creativity identifies four domains and is important because it clarifies a complex concept. The four domains are technical creativity, the concept, aesthetic creativity, and constructional creativity. Technical creativity was defined as asking the question, "Has the designer made proposals about the way the product will work and the nature of the components and materials required to achieve this? Is there something about these proposals that is novel or elegant?". In our study, we mainly searched for technical creativity within the scope of the definition above.

Researchers investigated the place of creativity in the national curricula of 27 European Union states and the United Kingdom (Wyse & Ferrari, 2015). Results indicated a need for much greater coherence between general aims for education and the representation of creativity in curriculum texts. Some studies have focused on the effect of various educational technology tools and systems on creativity at different grade levels (e.g., Auttawutikula, Wiwitkunkasemb & Smith, 2014; Lin, Yeh, Hung & Chang, 2013; Lloyd, 2013). However, to our knowledge, these important findings have not yet been synthesized. Therefore there is a need for a review of recent literature on creativity and technology in education, which will enable educators to better reflect on and implement technology in classrooms. According to Hokanson (2017) the most important factor in understanding the relationship between creativity and technology in education is the development of student creativity and how that creativity can be supported and developed by educational technologies. Although educational systems generally focus on the distribution and retention of knowledge, teaching and developing creativity is important for advancing innovation and technology in the field of education.

A systematic review of research can contribute much to the field under study. As Khan, Kunz, Kleijnen and Antes (2003, p.118) state, "A review earns the adjective 'systematic' if it is based on a clearly formulated question, identifies relevant studies, appraises their quality and summarizes the evidence by use of explicit methodology." Also known as research synthesis, "systematic reviews are summaries of past research on a topic of interest. However, unlike the traditional approach to reviewing literature, they utilize the same principles and rigor that is expected of primary research" (Joanna Briggs Institute, 2001, p.2). A clear indication of the methods is crucial in a systematic review, as indicated by the statement that "on completion of the review, the methods used are documented in the review report, as is done with all primary research, to allow users the opportunity to appraise the quality of the systematic review" (Joanna Briggs Institute, 2001, p.2).

Halcomb and Fernandez (2015) define the steps in the systematic review process as: i) planning the review (establishing a review team, formulation of research question, development of a review protocol, development of inclusion/exclusion criteria, ii) data collection (development of a search strategy, selecting included studies, reporting search results), iii) analysis and interpretation (assessing study quality, extracting data, analyzing results) and iv) dissemination of the review. Similarly, Khan et al. (2003) summarize the five steps of systematic review as i) framing the question, ii) identifying relevant work, iii) assessing the quality of studies, iv) summarizing evidence, and v) interpreting results.

The motivation behind this study was to grasp the overall picture in studies in which creativity was handled in environments where digital educational technologies were used. It must be kept in mind that technology itself is nothing in education, but all learning/teaching issues specific to a discipline and pedagogic aspects must be considered carefully in using such technologies in education. Creativity is one of the most important issues among such considerations, since creative thought and innovative problem solving skills are among the most necessary human characteristics in our globally developing century. The purpose of this study is to identify and synthesize articles in the field of creativity and education concerning the use of digital educational technologies and systems between 2013 and 2015 in Web of Science. To define the categories of digital educational technology, the New Media Consortium's Horizon Report (New Media Consortium, 2014) was used to develop a taxonomy illustrating the primary origin and use of technologies. We focused on the following categories: digital strategies, Internet technologies, learning technologies, social media technologies, and visual technologies. There are currently seven categories of technologies in the NMC monitors. "These are not a closed set, but rather are intended to provide a way to illustrate and organize emerging technologies into pathways of development that are or may be relevant to learning and creative inquiry" (NMC Horizon Report, 2014, p.34). Figure 1 shows the seven categories and key emerging technologies in each category.

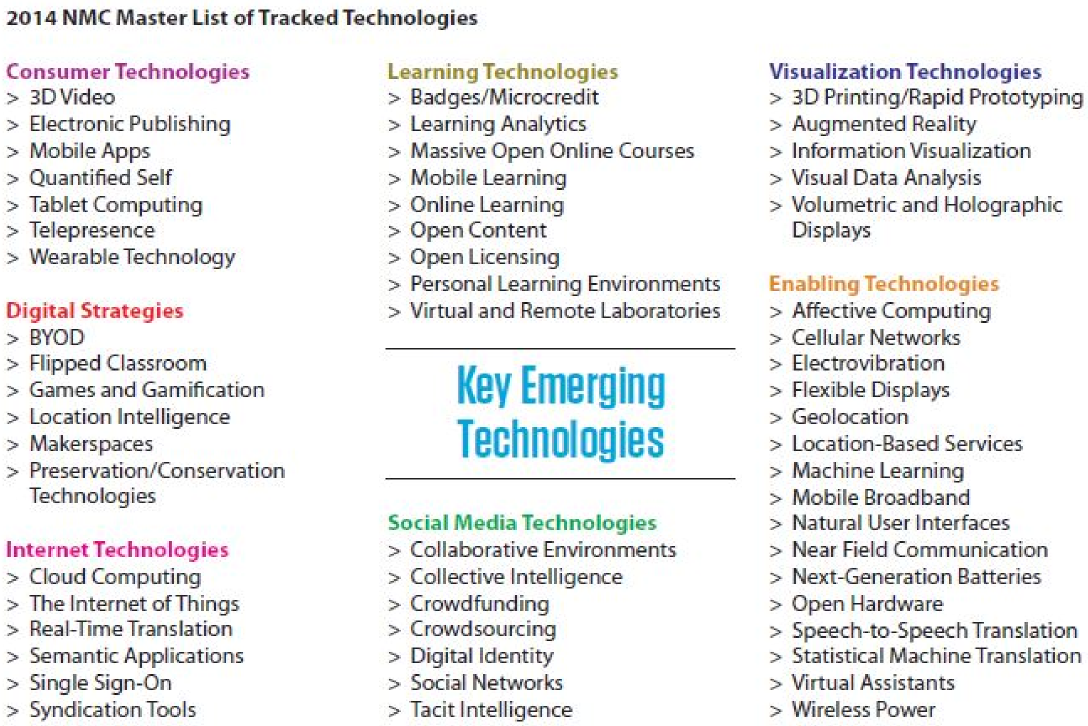

Fig. 1: List of Emerging Digital Technologies in Seven Categories, (NMC Horizon Report, 2014)

METHODOLOGY

We conducted a systematic literature review to synthesize literature related to creativity and education, concerning the use of educational technologies and systems. “How systematic reviews are conducted may vary and the methods used will ultimately depend on the question being asked” (Aromataris & Pearson, 2014, p.55). In this study, the review methodology was based on the five steps of systematic review proposed by Khan et al. (2003). Additionally, the systematic review for this study was conducted within one and a half years of performance.

Framing the Question

Systematic reviews ideally aim to answer specific questions, rather than simply to summarize all literature on a specified topic. It is also important to keep in mind that the main aim of a systematic review is to synthesize existing knowledge rather than to create new knowledge. In this study the main purpose was to identify and synthesize articles in the field of creativity and education concerning the use of digital educational technologies and systems. The main research question that guided this systematic review was: “What are the certain aspects (see section “Assessing the Quality of Work”) of studies in the field of digital emerging educational technologies that have focused on a student’s creativity?”. It also aimed to investigate signs of the impact of digital educational technologies on creativity in light of the selected papers.

Identifying the Relevant Work

As the second step of a systematic review an exhaustive search must be done for related studies, and it must be well documented. “The write up of the search should include information about the databases and interfaces searched (including the dates covered), full detailed search strategies (including any justifications for date or language restrictions) and the number of records retrieved” (Centre for Reviews and Dissemination, 2015, p.22). In the scope of our study, the detailed information regarding these was provided. A large amount of time and performance were devoted to “Assessing the Quality of Work” that started with stage 3. To draw a clear picture of the overall review process that was carried out through five consequent stages, the procedure was summarized in Figure 2.

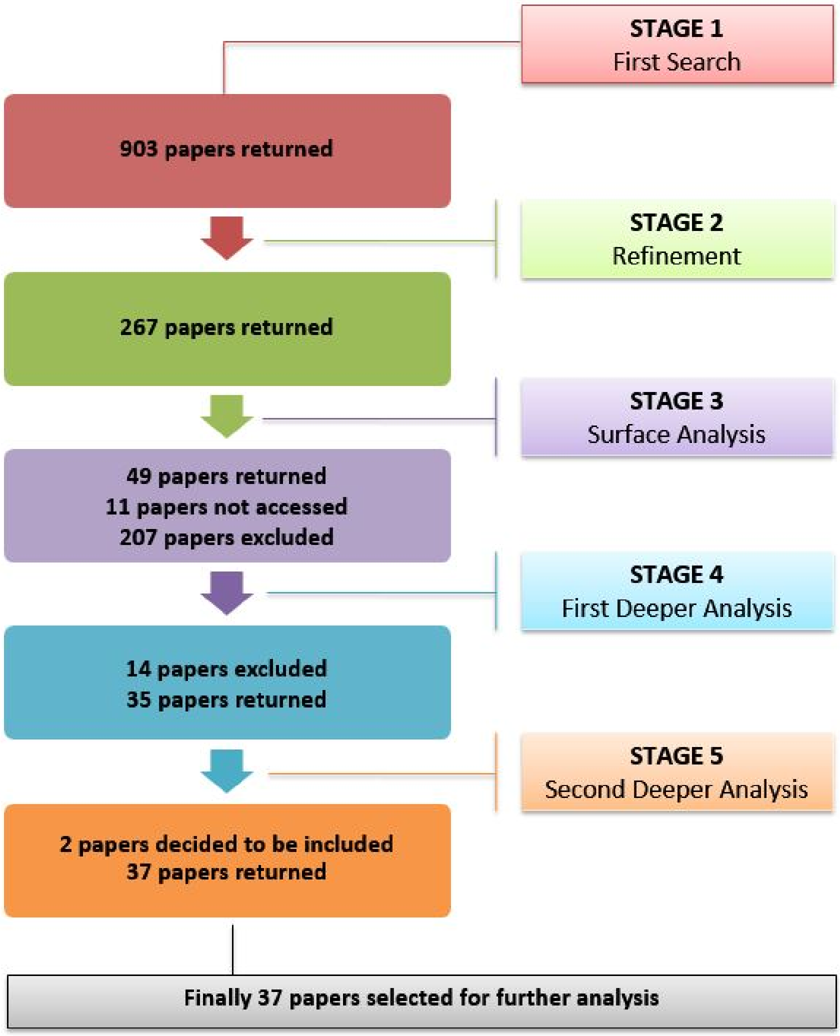

Fig. 2: Summary of all Review Stages and Procedures

In this study, identifying the relevant work started with the first stage; Web of Science was used as the main index, since our intention was to include only SSCI and SCI-expanded articles. The years 2013 to 2015 were covered. We entered the term "creativity and education" in the "topic" search field and selected "English" as the language option. As a result of this search, 903 records were returned. This first broad search was conducted to ensure that no relevant articles were missed. Next, we conducted several keyword searches, independent of the category selection, to verify that all relevant articles were included in the original search. These searches are summarized in Table 1.

Table 1. Keywords used in the review process

Category	Keywords
Creativity and education	• Creativity and educational technology • Creativity and distance education • Creativity and learning technologies • Creativity and e-learning • Creativity and Web 2.0

By comparing the results of the category search with the results of the keyword searches, we observed that the first category search contained all articles from each of the keyword searches, none having been missed out. Therefore, we continued the review using the 903 records obtained by the first search. Next, in the second stage, we refined our search by filtering results using the "social sciences", "education-educational research", and "only articles" options. As indicated in Figure 2, a total of 267 papers were found at the end of this first refinement.

Assessing the Quality of Work

The rest of the work required deeper investigations through analyses on papers. Both authors were involved in all stages of the analysis of papers, and a third colleague helped with the selection criteria. In stage 3, using the results of the first refinement (267 papers), we carefully conducted a surface analysis by reading the abstract, purpose, result, and conclusion of each article. Our main aim was to identify papers in which the existence of educational digital technology was overt and such technology's effects/relations on/with creativity were under investigation. Either such digital technology could be an environment in itself or the digital tools/materials used to enhance teaching and learning. The papers were given classifications in each of four main categories, as follows:

- General: information regarding the title, authors, publication year, journal name, country, number of times cited, keywords, and discipline.
- Methodology: information regarding the methodology, such as research method, number and level (K12, university, adults) of participants, problem and purpose of the study, variables, sampling method, type/category of educational technology used, data collection strategies and tools, analysis methods.
- Context: information regarding the discipline and topic studied and type of educational technology used.
- Results: information regarding the key results.

After this surface analysis eleven papers were excluded, since the full articles were not accessible. Based on the categories above, 49 papers were selected for further analysis (Figure 2 and Table 2).

Table 2. Papers selected to be reviewed as results of first search, refinement and surface analysis

Digital Library	No. of papers	First classification		
		Included	Not Accessed	Excluded
Web of Science	267	49	11	207
Total Percentage (%)	100	18	4	78

In stage 4, 49 papers selected in the third stage underwent a deeper analysis (Table 3). First, the two researchers reviewed the keywords of each paper. The papers were then subjected to another careful analysis, consisting of the abstract, method, and result sections, to verify that each paper was relevant to the scope of our study.

During this deeper analysis (in stage 4), papers having no clear relationship with any of the categories of educational technology mentioned in the NMC Horizon Report (2014) were excluded. Studies that clearly involved such educational technology but were not relevant to the direct effect of the technologies on creativity were also excluded. In total 14 papers were excluded; in 11 because the effect/consequences of digital educational technology or technology curriculum on creativity were not mentioned, and the main theme was not understood in three. The researchers were unable to make a decision about two papers, so a second deeper analysis was required for papers P2 and P43 in stage5. The role of technology in these papers was somewhat confusing. After that review, it was decided to include both Esjeholm's paper (P2) and Kim, Suh and Song's paper (P43). P2 involved technical creativity in the form of basic programming among students completing various projects via various digital tools. P43 was relevant because it reflected the participant-perceived effect of creativity on qualitative results. In total, 37 papers were selected for further analysis. The number of papers returned at stages 4 and 5 of the analysis process is indicated in Table 3. A summary of each selected paper, with its title, authors, source/journal name, and year of publication can be found in reference list which is indicated with"*".

Table 3. Final set of papers at the end of deeper analysis (Stages 4 and 5).

Digital Library	After Refinement	Total Selected	Excluded	Decided After Third Review	Final Exluded	Relevant (Final set of papers)
Web of Science	267	49	14	2	12	37
Total Per. (%)		100	29	4	24	76

At the end of stage 5, we conducted further analysis on each of the 37 identified papers to find an answer to our research question. This further analysis consisted of qualitative and quantitative assessment. Quantitative analysis consisted of descriptive statistics (frequencies and numbers), and qualitative analysis was performed to detail the characteristics of each study. The results of these analyses are presented in the next section.

Summary of the Evidence

Quantitative Analysis

The quantitative analysis that was conducted on selected papers is important since it gives us a general understanding regarding the general nature and appropriateness of those articles to our aim and enables us to make conclusions on the impact of technology on creativity in those papers. This analysis included determination of the name and distribution of the journals within Web of Science, the distribution of research methodologies used, research type, data collection methods, and type/level of participants. It is important to note that only the articles, which had a clear indication of these above categories were indicated in the tables. Table 4 presents the name and frequencies of each journal in 37 selected papers.

Table 4. Name and Distribution of 37 Returned Journals within Web of Science

Journal name	F
International Journal of Technology and Design Education	8
Computers & Education	3
Thinking Skills and Creativity	2
International Journal of Engineering Education	2
Educational Technology Research and Development	2
Innovations in Education and Teaching International	1
Journal of Education for Teaching	1
Eurasia Journal Of Mathematics Science And Technology Education	1
International Association for Research on Textbooks and Educational Media	1
Interactive Learning Environments	1
Music Education Research	1
Educational Technology International	1
Medical Education Online	1
Education and Science	1
Journal of Hospitality, Leisure, Sport & Tourism Education	1
British Journal of Educational Technology	1
Educational Technology & Society	1
Learning, Media and Technology	1
Journal of Computer Assisted Learning	1
The Asia-Pacific Education Researcher	1
BMC Medical Education	1
International Journal of Science Education	1
Cambridge Journal of Education	1
Journal of Geography in Higher Education	1
Australasian Journal of Educational Technology	1

In Table 4, the journal that includes the highest number of the publications within our returned 37 papers was "International Journal of Technology and Design Education". Other articles were distributed almost equally as presented in Table 4.

Knowing the main characteristics of the main research method applied in the selected papers is crucial to understanding how they explain the impact of educational technologies on creativity. Table 5 contains a summary of the papers based on the research method they followed. (In this and all related tables each paper that involved in more than on category were highlighted.

Table 5. Research method

Research method	Number of papers	Paper ID
Case Study	8	**P2**, P15, **P18**, P19, P20, P30, **P36**, P39
Survey	4	P6, P12 ,P37, P42
Experimental	23	**P2**, P3, P4, P5, P7, P8, P9, P10, P13, P14, P16, P17, P23, P25 ,P28, P29, P33, P34, P35, **P36**, P38, P41, P43
Action Research	1	**P18**

Correlational research	1	P24

Twenty-three of the papers used an experimental method, making this method the most common. In one of the papers, correlational research was conducted, eight of them used case studies, and three were based on surveys. Papers that used more than one method were reflected in related rows. For example, P2 and P36 were experimental case studies, and they are indicated in both rows in Table 5. Most studies followed experimental methods and case study was the second most preferred method. P22, and P40 were opinion/comment and P26 was literature review type articles, so no research method were mentioned in them.

Table 6 indicates the distribution of papers based on their data analysis method. Thirteen of the papers used only quantitative data analysis, nine of them used only qualitative methods, and 12 used both quantitative and qualitative methods. Here again P22, P26 and P40 was not included since they were literature review articles and did not include any analysis.

Table 6. Data analysis method

Data analysis method	**Number of papers**	**Paper ID**
Quantitative	13	P5, P6, P8, P12, P13, P16, P17, P20, P23, P24, P28, P29, P33
Qualitative	9	P2, P10, P14, P15, P18, P19, P37, P39, P43
Quantitative/Qualitative	12	P3, P4, P7, P9, P25, P30, P34, P35 P36, P38, P41, P42

A summary of the papers based on their data collection method is shown in Table 7, with 21 of the papers using questionnaires/scales, two using video tapes as documentation, two using a learner analysis system for log analysis, eight using observation, and five using rubrics to evaluate overall performance/product.

Table 7. Data collection method

Data collection method	**Number of papers**	**Paper ID**
Questionnaire/scale	22	**P3**, P6, P7, P8, **P4**, P12, P13, P16, , P20, P23, P24, **P25**, P28, P29, **P30**, **P33**, **P34, P35**, **P36**, **P37**, **P41**, P42
Video tapes documentation	2	**P2**, P14
Learner analysis system (log analysis)	2	P5, P38
Observation	8	P2, **P4**, P9, P14, P36, **P38**, **P43**
Focus group discussions	3	P10, **P37**, P39
Interviews	4	P10, P15, P19, **P41**
Conversation	1	P14
Achievement test	4	P16, **P25**, **P33**, **P34**
International objective structured clinical examination	1	P17
Structured open ended questions	4	**P3**, P18, **P34**, **P41**
Messages / content analysis	3	P25, **P30**, **P38**
Rubric	5	**P2**, P25, **P35**, **P36**, **P43**
Peer Assessment	1	**P43**

As indicated in Table 7, questionnaire/scale was the most preferred data collection method among all the papers. Interestingly, a wide variety of data collection methods were used. Table 8 presents the level and number of individuals in papers involving participants. Eighteen papers reported that the participants were university students, and 12 papers were focused on K12 students (Figure 3). P12 and P42 as survey studies, had the largest number of participants (n = 1181 and n = 4496).

Table 8. Level of participants

Paper ID	Participants' Level	Number	Type
P3	University	41	Student
P6	University	350	Student
P7	University	107	Student
P2	K12	104	Student
P4	Adults	100	Teacher
P5	K12	92	Student
P8	K12	132	Student
P9	K12	200	Student
P10	University	72	Student
P12	K12	1181	Student
P13	K12	33	Student
P14	University	8	Student
P15	University	9	Student
P16	University	100	Student
P17	University	203	Student
P18	University	16	Student
P19	Adults (mean age 38)	3	Musicians
P20	University	137	Student
P23	University	55	Student
P24	University	597	Student
P25	K12	131	Student
P28	University	104	Student
P29	K12	349	Student
P30	University	93	Student
P33	University	229	Student
P34	K12	167	Student
P35	K12	28	Student
P36	University	Not indicated	Student
P38	K12	229	Student
P39	University	20	Student
P41	University	137	Student
P43	K12	30	Student

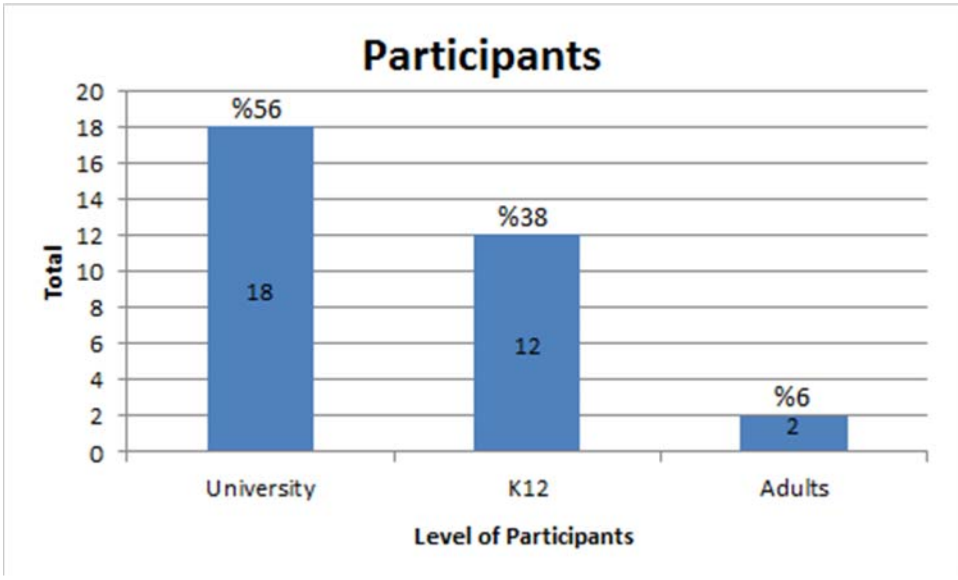

Fig. 3: Level of Participants

Qualitative Analysis
For this process, two researchers were involved in coding independently. Coding agreement was found to be 88% following this procedure. Disagreements between the two coders were resolved through discussions.

Qualitative analysis was based on the content analysis of selected papers and expected to contribute to our research questions. The main intention of such analysis was to discriminate between papers based on predetermined NMC categories and also to build categories and/or subcategories that; i. identify the emerging educational technology used in those papers overtly and ii. investigate the impacts of them on creativity. So, the results of this analysis contributing first part (i) were explained below with references to Table 9.

Besides divisions based on educational technology, "the impact/result of using that technology" was mentioned in Table 10 and Table 11. Those tables mainly serve to reflect the nature of the research papers regarding variables and results/impacts. It must be kept in mind that only papers having a clear indication of their research methodologies were included in all parts.

Emerging Educational Technology Used
In order to discriminate between the main educational technology used in each paper, we used NMC Horizon Report's (2014) categorization of emerging technologies (Figure 1). To do so, we carefully read each paper again to identify the appropriate category for each educational technology. The main difficulty here was identifying the "emerging technology" itself. As an example, computer-aided design (CAD) software was used as a graphic design tool in paper P9, but CAD might not be considered as an emerging tool, because it has been used for many years. We overcame this confusion by referencing Miller, Green and Putland (2005), who stated that a technology is still emerging if it is not a "must have" for the users. Thus, educational technologies that were not must-haves for the studies' participants were regarded as emerging technologies. Results were summarized in Table 9.

Content analysis indicated that papers P2, P4, P12, P22, P26, P35, P37, P40 and P42 studied the effect of technology-driven programs/projects instead of educational digital technology itself. Thus, we divided the papers into two categories: i) Digital Technology/System and ii) Curriculum/Program (Table 9, first column). Our categorization in that direction provided a new and very distinctive framework. In Table 9, the main NMC categorization was given as a subcategorization under these two. Papers addressing this were also indicated in the last column with their ID numbers. It is worth noting that paper P2 was included in both categories.

Under our Curriculum/Program division in Table 9, the main intention of the papers was to study/discuss the contribution of a technology-related curriculum/program in terms of creativity. In that division, the educational technology used was overt in papers P2, P22 and P26. As part of the problem/project approach followed in paper P2, multiple educational technologies, such as Lego robotics and Google SketchUp, were used. The main educational technology discussed in paper P22 was Twitter; the authors considered the effects that using such media technology in curricula had on student creativity. By contrast, the focus of P26 was enabling technologies/machine learning. Here, the chain effect of creativity on neuroscientific development, as well as neuroscience-specific curriculum developments on enhancement of educational tools that support creativity, were discussed. In all other papers under the Curriculum/Program division, the main focus was studying/discussing the contribution of a technology-specific curriculum/program itself to creativity. The Curriculum/Program projects were a professional learning program (in P4), a human being and technology program (in P12), a curriculum containing computer technology-integrated projects (in P35), a project called the Designing Our Tomorrow (Dot) Project (in P37), a technology curriculum (in P40), and a design & technology (D&T) education curriculum (in P42).

Table 9. Results of qualitative analysis of educational technology used

Main	NMC Categorization of Technology	Technology Used/Content	Paper ID
EMERGING DIGITAL TECHNOLOGY/SYSTEM	Enabling Technologies /Machine Learning-Robotics	Lego-Robotics	**P2**
	Total		1
	Social Media Technologies/Social Networks	Weblogs	P3
	Social Media Technologies/Social Networks	Podcast	P15
	Social Media Technologies/Collaborative Environments	Knowledge Forum-A Knowledge Building Environment	P30
	Total		3
	Learning Technologies/Learner Analysis	Data Mining-Learner Analytics	P5
	Learning Technologies/Online Learning	Web 2.0 Learning Environment	P6
	Learning Technologies/Personal Learning Environments	Web-Based Creative Problem Solving (CPS v3.)	P7
	Learning Technologies/Open Content	Open Ended Materials	P18
	Learning Technologies/Personal Learning Environments (Courseware and storyboarding)	CFD (Computational Fluid Dynamics), CAM (Computer Aided Manufacturing), FEM (Finite Element Method), CAD (Computer Aided Design) software	P36
	Learning Technologies	Concept Map Knowledge Management System	P38
	Learning Technologies	Film	P39
	Learning Technologies	Mindtools, Mind Mapping Tool	P41
	Total		8
	Visualization Technologies/Information Visualization	Science Fiction Film	P8
	Visualization Technologies/Information Visualization	Simulated Virtual Reality, Simulations, Virtual Reality Teams	P14, P17, P19, P20
	Visualization Technologies/Information Visualization	Virtual Microscope (VM) System	P33
	Visualization Technologies/Visual Data Analysis	Google SketchUp	**P2**
	Visualization Technologies/Visual Data Analysis	Computer Aided Design (CAD) Tools	P9, P24
	Visualization Technologies/Visual Data Analysis	Three-Dimensional Computer-Assisted Drawing (3D-CAD)	P29
	Visualization Technologies/Augmented reality	3D Modeling Software	P13
	Total		11
	Internet Technologies	Learner-Created Digital Storytelling	P16
	Internet Technologies	Storyboard	P28
	Total		2
	Digital Strategies/Games and Gamification	Simulation games	P10
	Digital Strategies/Flipped Classroom	Web 2.0 Tools	P23
	Digital Strategies/Games and Gamification	Minecraft Edu: Video Games	P25
	Digital Strategies/Games and Gamification	Educational Computer Games	P34
	Total		4
	Consumer Technologies/Mobile Apps	Mobile Phones	P43
	Total		1

Main	Intend for Creativity/NMC Category of Tech.	Curriculum/Program/Content	Paper ID
CURRICULUM / PROGRAM	Enabling technologies/Machine learning-robotics Visualization technologies/Visual data analysis	Problem/Project Based Approaches	**P2**
	Effects of program including development of innovative science learning and assessment activities	Professional Learning Program	P4
	Program evaluation-Including creativity dimension	Human Being and Technology	P12
	Social media technologies/Twitter	Twitter-Curriculum-Activity Suggestions for Sport Management	P22
	Enabling technologies/Machine learning	Technology-Enhanced Learning-Neuroscientific Concepts	P26
	Comparison effect of analog/computer tools on creativity	Computer Technology-Integrated Projects	P35
	Student opinions on effect of program on their creativity	The Designing Our Tomorrow (Dot) Project (Inclusive Design Materials & Principles)	P37
	Discussions on technology curriculum. vs creativity	Effective Design Thinking For Technological Literacy-Technology Curriculum	P40
	Teacher and student views on contributions of curriculum to creativity	Design & Technology (D&T) Education Curriculum	P42
	Total		9

Under the main Digital Technology division in Table 9, papers P2, P3, P5, P6, P7, P8, P9, P10, P13, P14, P15, P16, P17, P18, P19, P20, P23, P24, P25, P28, P29, P30, P33, P34, P36, P38, P39, P41 and P43 all focused on the effect of the digital technology/system itself. Here, each paper was summarized using the NMC categories (Figure 1) for convenience and clarity of the results. In the Digital Technology/System category, we faced a little difficulty in identifying NMC Categorization of technology, since the appropriate subcategory was not always clear. Those cases were placed only under the main category of Digital Technology in Table 9. We observed that sometimes more than one category could apply to a single technology, depending on how the technology was used. Thus, there could be variations in our categorization resulting from an inability to determine from the papers how a technology was used. Not all possible subcategories are indicated in the table.

In addition to being placed in two divisions in Table 9, paper P2 was also placed under two different subcategories within the Digital Technology division. Two educational technologies in the categories of Enabling Technologies/Machine Learning-Robotics and Visualization Technologies/Visual Data Analysis were used in this paper. The aim of paper P2 was to study the effect of students' technology knowledge on creativity. In that paper, Bjorn-Tore Esjeholm (2015) studied the effect of the technology knowledge that students already had to use in their projects. In their projects, students used various educational technologies, hence the multiple categorization was realized.

Social media technologies were identified in papers P3, P15, and P30. In P3, Auttawutikula, Wiwitkunkasemb and Smith (2014) studied the effect of using weblogs as a social network on university students' attitudes toward weblogs, their achievement, and their creativity. They indicated a significant improvement in assessed creativity among students using weblogs. In this study, weblogs were perceived as enhancing both group learning and creativity, allowing students to more freely show individual creativity within an enhanced peer collectivism structure. In P15, Bolden and Nahachewsky (2015) qualitatively studied students' experiences of creating podcasts in an undergraduate music education course. Nine participants were interviewed about their experiences of podcast creation. Their results indicated the potential of podcast creation to enable learners to exercise creativity. Paper P30, by Hong (2014), was placed in the Social Media Technologies category with a Collaborative Environments subcategory. Hong, among 93 prospective teachers, investigated perceptions of a collaborative learning environment in which a knowledge form was used. The results of that study indicated that students saw the environment not only as supporting knowledge acquisition, but also as providing knowledge creation.

Educational technologies under the Learning Technologies category were studied in papers P5, P6, P7, P18, P36, P38, P39, and P41. In their study (P5), Lin, Yeh, Hung and Chang (2013) developed a personalized creativity learning system (PCLS) based on the data mining technique. Their system provided personalized learning paths for optimizing the performance of creativity in students. Among the 92 college student participants, the data mining technique was a good vehicle for providing adaptive learning, which is related to creativity. In a survey study (P6), emphasizing the effect of Web 2.0 online learning systems, Lloyd (2013) studied the elements of an online learning environment and reflected on students' perceptions regarding its effects, including on creativity. In paper P7, Chang (2013) investigated the effects of online (web-based) creative problem-solving (CPS) activities on student technological creativity and examined the characteristics of student creativity in the context of online CPS among 107 fourth-grade students. The results of the quantitative analysis revealed that the technological creativity of the students using online CPS was better than that of the traditional group. Mirzaoglu (2015) concluded that classroom teacher candidates defined the open-ended materials as developing creativity, but also as confusing (P18). In their study (P36), Rivera-Solorio, Alejandro, Cuellar and Flores (2014) declared that a project based engineering university course which supported with computational tools increased students' creativity. Liu and Lee (2013) in paper P38 aimed to observe changes in students' understanding of biological concepts over time. Their study revealed that use of Concept Map Management System had a positive influence in promoting students' creativity. In P39, (Anderson, 2013), the strategies that students used were investigated to capture creativity during a digital film production by students. Wu, Hwang, Kuo and Huang's (2013) study (P41) related to the effect of a Mindtool-based collaborative learning approach on students' innovative performance. The results of this experimental study indicated that use of such digital technology and approach significantly enhanced students' innovative performance in a project based learning task.

Educational technologies under the Visualization Technologies category were studied in papers P2, P8, P9, P13, P14, P17, P19, P20, P24, P29, and P33. Interestingly, in paper P8, Lin, Tsai, Chien and Chang (2013) focused on the effects of a learning activity based on a science fiction film on the technological creativity of middle-school students. A quasi-experimental design was employed, and 132 middle school students were included in this study. It was found that science fiction films could stimulate middle-school students' technological creativity. Similarly, Laisney and Brandt-Pomares (2014), in paper P9, sought to determine the influence of a CAD tool on technological creativity among students on a technology course. The results showed that using traditional drawing before CAD tools allowed the pupils to develop quantitatively more solutions. Wong Lau and Yuen Lee (2015) discussed the roles of simulation in creativity education and discussed on how to apply immersive virtual environments to enhance students' learning experiences in university (P14). The results of this study showed that virtual reality could possibly enhance students' learning experiences and encourage creativity. As the digital technology was simulations in P17, the results were mentioned mainly for the effect of using such technology on clinical skills. In that paper, although the creativity component was not very clear, Zhang, Cheng, Xu, Luo and Yang (2015) found that the use of digital simulative training could significantly enhance the graduate score of medical students. In paper P19, Biasutti (2015) aimed to define how creativity was expressed and supported during the collaborative online composition of a new music piece employed by adult musicians. Their findings indicated that collaborative creativity involved musical and social practices. Čok, Fain, Vukašinovic and Zavbi (2015) investigated the influence of the (multi-) cultural background of virtual team members on the team's creativity and design features, and they developed a conceptual framework to test such an influence (P20). The results showed significant differences within such factors based on cultural variations. In their correlational research design in paper P20, Dawoud, Al-Samarraie and Zaqout (2015) studied the relationship between flow experience and creative behavior in design using CAD. They concluded that flow experiences partially mediate the relationship between the interactivity of CAD and creative behavior in design. In their experimental study (P33), Tian, Xiao, Li, Liu, Qin, Wu, Xio and Li (2014) analyzed the effect of using virtual microscop-VR on medical students' active learning, problem solving skills and creativity. While no significant differences were observed between achievement of VR and traditional groups based on their mean scores from multiple choice and short essay questions, the questionnaire results indicated that the VM system improves students' productivity and promotes learning efficiency. In paper P29, the main theme was based around the three dimensional computer assisted drawing tool in which the results showed that 3D-CAD applications enhanced K12 students' creative performance (Chang, 2014).

Educational technologies under the Internet Technologies category were studied in papers P16 and P28. In an experimental study by Kim (2016), the results indicated that there was a significant difference between the groups using digital storytelling (DST) and those using expository instruction on behalf of the DST group (in P16). The main digital technology under study was storyboards in the experimental study of Teng, Cai and Yu (2014).

Educational technologies under the Digital Strategies/Games and Gamification category were studied in papers

P10, P25 and P34. Mažeikienė and Gerulaitienė (2015) in P10 suggested that simulation games encourage the development of students' ability to create multimodal texts. In P25, Sáez-López et.al (2015) stated that the majority of K12 students found video games to be enhancing their creativity. Hwang, Hung and Chen (2013) in their study (P34) indicated that most of their participants as K12 students perceived peer assessment-based game development helped them to improve creativity.

Educational technologies under the Consumer Technologies category were studied in paper P43. In their study, Kim, Suh and Song (2015) investigated the consequences of team game developments with the support of mobile phones. The results of this experimental study proposed that most of the participant K12 students (in an experimental group) perceived that peer assessment-based game development improved their creativity.

Variables and Impacts/results of studies

Here, signs of the impact of digital educational technologies on creativity in scope of those selected papers were re-studied and summarized. In addition to the results above, here we mainly intended to reflect the results of our content analysis based on research characteristics such as variables and impacts. In doing so, papers indicated in Table 6 underwent such analysis. Paper P6, which is indicated as a quantitative study in Table 6, was a survey study, but its variables and impact could not be clearly identified. Therefore, we omitted that paper in Table 10 (on the other hand, P22, P26 and P40 were theoretical studies and they were also eliminated in both tables). Regarding our qualitative analysis based on ***"quantitative"*** papers, we presented dependent (we took mainly creativity-related ones) and independent variables, and the impact of the digital educational technology/program on creativity for each study in Table 10. On the other hand, same procedure for ***"qualitative"*** papers was reflected in Table 11. P2 were placed under three different categories in Table 11 and highlighted.

Table 10. Results of qualitative analysis for variables and impact of digital educ. tech/program in quantitative studies

Paper	Dependent Variable/s	Independent Variable/s	Result-Impact ↑ means positive impacts ↓ means negative impacts
SOCIAL MEDIA			
P3	-Group learning Creativity	Use of weblogs	↑"Results showed a significant improvement in assessed creativity at the end of the trial period with weblogs being perceived as enhancing both group learning and creativity"
P30	-Knowledge building and creation (Construct creativity)	Use of knowledge forms	↑There was a significant difference between notes-built on before and after the treatment.
LEARNING TECHNOLOGIES			
P5	-Creativity	Use data mining technique to provide personalized learning	↑ "The experimental results show that, when the learning path suggested by a hybrid decision tree is employed, the learners have a 90% probability of obtaining an above-average creativity score"
P7	-Technological creativity	Use of online problem solving activities	↑ "The quantitative analysis revealed that the technological creativity of the online-problem solving students was better than that of the traditional group."
P36	-Design creativity	Use of computational tools (CFD, FEM, CAM and CAD)	↑"Student creativity was challenged appropriately through CFD,FEM,CAM and CAD tools"
P41	-Creativity-students' innovative performance	Use of Mindtool based collaborative approach	↑The experimental results that use of that approach significantly enhanced the students' innovative performance in a project-based learning task.
VISUALIZATION TECHNOLOGIES			
P8	-Technological creativity	Use of science fiction films in a lesson	↑Students creativity were higher at experimental group

P13	-Creativity -Learner motivation -Achievement as basic knowledge and skills	Use of augmented reality	↑Students creativity were higher at experimental group
P17	-Clinic skills including clinic innovations-creativity	Use of simulations in clinical training of medical students	↑ "The results revealed that simulative training could significantly enhance the graduate score of medical students compared with the control"
P20	-Team's creativity -Design Process	1.Cultural background of virtual team members. 2. Creativity	↑Background-Working in virtual teams has a positive effect on creativity in new product development.
P33	-Students' productivity	Use of visual microscope system.	↑Results from the questionnaire indicated that VM system improves student's productivity.
P9	-Student's performance -Creativity as finding new ways to solutions	Use of graphic tools	↑Control group's solutions were more creative
P24	-Creative behavior in design	Flow experience	↑Both the characteristics of a design task and the interactivity of CAD were positively predicted the experience of flow
P29	-Creativity	1.Use of 3D CAD applications 2.Spatial ability	↑Results indicated that "students' spatial abilities were moderately correlated with their creative performance, especially their functional creativity; (2) the 3D-CAD applications enhanced students' creative performance, particularly with regard to aesthetics; and (3) in 3D-CAD applications, students with better spatial abilities were superior to those with relatively poor spatial abilities with regard to creative performance."
INTERNET TECHNOLOGIES			
P16	-Creativity -Achievement -Flow State	Use of digital story in "Introduction to Special Education" course	↑Students creativity were higher at experimental group
P28	-Creativity -Structure -Drawing skills	Gender Use of storyboards	↑Results show that larger numbers of words and images correlate with good word and image ideas and that analytic females exhibited the greatest level of ideation and intuitive males exhibited the least.
DIGITAL STRATEGIES			
P25	-Creativity -Attitudes	Use of video games	↑Experimental group's rating for the effectiveness of video games to enhance creativity was higher than control group.
P23	-Creative thinking	Use of flipped classroom	↑The findings suggest that the flipped classroom may promote students' creativity, especially with regard to fluency, flexibility and novelty.
P34	-Achievement, -Motivation, -Problem solving skills	Effects of peer assessment based game development approach.	↑Beside other findings, it was also found that most of the students perceived "peer assessment-based game development" as an effective learning strategy that helped them improve their deep learning in terms of ''in-depth thinking,'' ''*creativity*,'' and ''motivation.
CURRICULUM/PROGRAM/CONTENT			

P4	-Creativity at Design for Learning Activities	Impact of "Professional Learning Programme"	↑The study found that the participants made substantial progress towards the development of innovative science learning and assessment activities.
P12	-Activity know-how of technology" including new ideas	Applying a national curriculum with theme "Human Being and Technology"	↑As the part of the results of evaluation of curriculum theme "Human Being and Technology", majority of students declared that this programme would encourage them towards innovativeness and creativity.
P35	-Creativity	Effects of computer technology integrated curriculum	↑Findings indicate student products were more creative after analogy-based instruction and when made using technology.
P42	-Creativity	Use of practices in "Creativity in Design & Techology"	↓Findings indicated that did not perceive that practices in their classrooms as conducive for creativity. Teachers' perceptions differed somewhat as they indicated that they can change their practice to enable creativity to flourish

Table 11. Results of qualitative analysis for impact of digital educ. tech/program on creativity in qualitative studies

Paper	Category/Themes	Phenomenon/ Case studied	Result ↑ means positive impacts ↓ means negative impacts
SOCIAL MEDIA			
P15	Creativity meaningful knowledge construction self-expression collaboratively developing knowledge combining text and music	Applying podcast creation activities	↑ Findings include the potential of podcast creation to enable learners to exercise creativity
LEARNING TECHNOLOGIES			
P18	Open ended materials enhancing creativity	Use of open ended materials in prospective teachers' training	↑ "The results showed that classroom teacher candidates defined the open-ended materials as developing creativity, are useful, easy to find, safe/harmless but also as confusing. "
P38	Creativity in collaborative groups	Use of the concept map knowledge management system	↑ "The concept map knowledge management system also was useful in promoting the student's thought processing, creativity, and ability to judge"
P39	Creativity in communication	Integrating film production into the assessment of undergraduate modules	↑ Students' opinions presented that reflecting on their experience of producing films as part of an assessment strategy contributed to their own development including creativity
ENABLING TECHNOLOGIES			
P2	Creativity (Conceptual, aesthetical, technical and constructional creativity each)	Degree of prior design knowledge	↑ "Students' limited conceptual technological knowledge constrains their ability to be creative and to produce genuine solutions." "The results also reveal that the projects showing less student creativity tend to be more controlled by the teacher and less open-ended than presupposed."
VISUALIZATION TECHNOLOGIES			
P2	Creativity (Conceptual, aesthetical, technical and	Degree of prior design knowledge	↑"Students' limited conceptual technological knowledge constrains their ability to be creative

	constructional creativity each)		and to produce genuine solutions." "The results also reveal that the projects showing less student creativity tend to be more controlled by the teacher and less open-ended than presupposed."
P14	QUALITATIVE CATEGORY: Creativity	Virtual reality-integration of interactive simulations	↑ "Being explorative and fun were essential parts of the students' learning experience in the virtual reality in this research."
P19	The study's aim is to analyze the collaborative creativity and peer collaboration employed during the online music composition.	Use of online music composition for musicians	↑ Creative processes were expressed effectively in online collaborative activities.
DIGITAL STRATEGIES			
P10	Ability to create multimodal texts	Use of simulation games	↑ Additionally, "simulation games provide a multimodal platform, encouraging the development of students' ability to create, read and interpret multimodal texts."
CONSUMER TECHNOLOGIES			
P43	Design Creativity	Use of mobile phones in science classroom	↑ "Mobile technology can be used as a scaffolding tool for students' imagination, creativity, and finally improved designs"
CURRICULUM/PROGRAM/CONTENT			
P2	Creativity (Conceptual, aesthetical, technical and constructional creativity each)	Degree of prior design knowledge	↑ "Students' limited conceptual technological knowledge constrains their ability to be creative and to produce genuine solutions." "The results also reveal that the projects showing less student creativity tend to be more controlled by the teacher and less open-ended than presupposed."
P37	Creativity	Students' views on "Designing our Tomorrow-DOT" approach	↑ Students indicated that their creativity and empathy were enhanced following their engagement with the intervention materials.

As seen from Table 11, categories regarding the definitions of creativity varied through conceptual, aesthetic and technical domains. We found in articles the tracks of such domains through explained situations in them, such as meaningful knowledge construction (P15), creativity in collaborative groups (P38, P19), creativity in communication (P39), and again creativity in design (P43). Interestingly P2 studied conceptual, aesthetic, technical and constructional creativities at the same time. It is important to note that discriminating between those domains of creativity was not so easy and the definitions in articles greatly enabled comprehension. Impacts have been reported mostly in terms of the achievements, attitudes and opinions of students.

Interpretation of the Results

In this section, interpretation of results was performed in two ways: procedural self-criticism of our systematic review itself and as conclusions based on the overall characteristics and results of the investigated papers.

The purpose of this systematic review was to synthesize literature related to creativity and education concerning the use of educational technologies and systems. The results revealed some interesting findings relevant to this field of research. First, the search that was conducted using only the topic "creativity and education" returned a wide range of papers, in which it was difficult to locate those papers emphasizing educational technology and creativity. Using sub-keywords was successful in narrowing the search to related papers. We believe that limiting the search only to papers written in English was a handicap, since otherwise we might have covered many more quality papers.

It was difficult to identify the research method in some studies. For such papers, repeated readings by multiple researchers were required. It was observed that, in the majority of papers, experimental methods were used, with more variety pertaining to qualitative versus quantitative research and the specific data collection tools used. This variety was somehow a good indication of the quality of the work in selected papers. As noted earlier, studies that focused on the effect of educational tools on creativity were almost equally distributed among K2 and university levels. However, the number of studies focusing on adults in lifelong learning to enhance creativity was very limited.

The educational technologies used in selected studies were overtly identified. Since our main focus was educational technology and creativity-related studies, our analysis focused first on papers describing the effect of an educational tool or system on creativity. Our effort to categorize technologies in terms of NMC categories of emerging technologies yielded a clear picture of the distribution of studies among those categories. However, we also examined studies using the curriculum/program approach. Thus, our qualitative analysis revealed a new way of categorizing educational technology and creativity-related papers. Specifically, we categorized papers as related to i) Digital Technology or ii) Curriculum/Program. This division resulted in a more detailed understanding of current research. This supported a better grasp of the main phenomena in that field of study. A further review of the studies in the Curriculum/Program division revealed the effects of new designs or approaches in technology-related subjects on creativity, yielding more insight into the field of study under review.

It is interesting to note our progress in locating papers using specific educational technologies under specific categories defined by NMC. Although the titles of papers made it easy to determine the technology that each paper was focused on, finding an appropriate sub category was confusing in some cases. We had previously predicted that situation would be faced, as it would arise when dealing with various digital educational technologies especially in an effort to categorize them.

Qualitative analysis results show that “creativity” was taken as the dependent variable or categorization/theme of the search in almost all those studies. Through our analysis, there were some clear distinctions regarding the domain of creativity. Technical and design creativity was the most common variable. It is important to note that collaborative creativity, knowledge creation, innovative performance and new ideas for solutions were important attributes in related studies. New dimensions based on those attributes in future studies are expected.

IMPLICATIONS OF THIS STUDY FOR THEORY AND PRACTICE

In this study, first of all the systematic analysis provided a deeper understanding of the literature in that area in that time span. Analysis has revealed that the majority of the studies were either empirical and/or descriptive ones (using qualitative, quantitative and triangular methods). This in turn indicated that the results of such collected work attributed to the area to suggest a general overview of creativity in the use of educational technology in learning/teaching environments. According to the qualitative and quantitative analysis results of this study, it has been observed that the results of almost all of the papers indicated positive effects/improvements of using educational technology in students’ creativity and attitudes towards the subject of study (Tables 10 and 11).

On the other hand, the results of this study would appear to be also an indication of the shift in the use of certain educational technologies between certain time spans and in the focus of researchers’ attention on studies in the field of creativity and education concerning the use of digital educational technologies and systems in those years. The mostly investigated educational technology (in terms of its contribution to creativity) within the specified time span in this study was visual technologies such as visual reality tools and 3D modeling software. The second investigated educational technology in terms of its contributions to creativity was learning technologies including learning analytics and knowledge management systems. As a summary:

- The systematic analysis in the field of creativity and use of digital educational technologies provides a deeper understanding of the literature in that area.
- The categorization as i. the digital technologies themselves and, ii. Curriculum/Program provides a new framework in the area.
- The discussion of the articles within the scope of this systematic analysis helps to gain perspectives on the contributions of using digital educational technologies on creativity.

On the other hand, as implications for practice and/or policy

- The application of both technology and curriculum perspectives provided in our study, should be used for further analysis of future developments in the field of emerging digital educational technologies and learning.
- Finally, conducting meta-analysis on that aspect of the papers would contribute much to the area of study

and reveal direction for future research.

- Additional research on the impact of digital technology on creativity in adult education and lifelong learning is required.

LIMITATIONS

One of the major limitations of this study is the selection of papers based on time scope between 2013 and 2015. Another major limitation was the selection of papers based on Web of Science Index (SSCI and SCI indexed ones). It is not the intention of systematic review studies to include all or many databases. Rather a detailed investigation on the selected collection was realized in this study. It is suggested that future studies could be conducted to include larger databases. The use of keywords was another limitation. Also, this systematic research is only limited to the 25 journals. These journals' language was only in English, so this does not represent the articles that were written in other languages. Another limitation of this study lies in the qualitative analysis based on NMC categories of educational technologies. Here, our suggestion is to include other possible digital educational technology categories in that theme for further studies.

CONCLUSION

This systematic review resulted in a good indication of the state of research related to educational technology and creativity published from 2013 to 2015. Both quantitative and qualitative analyses presented interesting findings related to the topic of creativity and educational technology. Based on the data collected, it was possible to make the following conclusions. First, this systematic analysis in the field of creativity and use of digital educational technologies would help for a deeper understanding of the literature in that area. Also, the categorization in this study as; i. digital technologies themselves and, ii. Curriculum/Program would provide a new framework in the area. The discussion of articles within the scope of this systematic analysis helps to gain perspectives on the contributions of using digital educational technologies on creativity. Additionally, this systematic review indicates that research related to educational technology and creativity is of a good quality overall. The results of this study indicate that "technical creativity" was the most common variable within the domains of creativity. We conclude that whatever the domain is, the impact of using the above-mentioned digital educational technology was positive in all investigated papers. As suggestions:

1. There is a need for more studies addressing the effect of educational technology on creativity among various levels of participants, especially adults.
2. There is a need for more studies addressing the effect on creativity of technology-related curricula/programs or approaches.
3. There is a need for more studies comparing the effect on creativity of using various teaching methods with the same technology.
4. There is a need for more systematic review studies involving detailed analyses based on the quantitative results of papers, as well as data collection tools. This also calls for meta-analysis studies.
5. There is a need for more systematic review studies focused on the same research theme as addressed in this study, with emphasis on other categorizations of digital educational technology, such as those updated reports of NMC higher education and K12.

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