On making, tinkering, coding and play for learning: A review of current research

Stella Timotheou[1] and Andri Ioannou[1,2] [0000-0002-3570-6578]
[1] Cyprus Interaction Lab, Cyprus University of Technology, Limassol, Cyprus
[2] Research center on Interactive media, Smart systems and Emerging technologies (RISE), Nicosia, Cyprus
andri@cyprusinteractionlab.com
stella@cyprusinteractionlab.com

Abstract. Although a few researchers have recently focused on the value of making, tinkering, coding, and play in learning, a synthesis of this work is currently missing, creating an unclear path for future research in this area. Computational-making-enhanced activities, framed as activities promoting making, tinkering, coding and play in the learning process, have gained a lot of attention during the last decade. This study provides a review of the existing research in this area, published in academic journals, from 2009 to 2018. We examine learning gains linked to learners' participation in computational making-enhanced activities in formal and non-formal education settings. We further overview the research methods, the educational level, and the context of the published studies. The review of selected studies has shown that most of the research has been conducted in non-formal and informal education settings, however a shift to formal education has appeared since 2016. Most studies have focused on programming and computer science with middle-school learners. Immediate action is needed to inform the design of computational-making-enhanced activities directly linked to curriculum goals. Given the lack of synthesis of work on computational-making, the review can have considerable value for researchers and practitioners in the field.

Keywords: Making, Tinkering, Coding, Play, Computational making, Technology-enhanced learning.

1 Introduction

Current research findings support that making and tinkering activities can help with the development of skills, such as creativity, innovation, problem-solving, programming and computational thinking skills, which constitute the 21st century skill-set (Bevan et al., 2015; Moriwaki et al., 2012; Harnett et al., 2015; Kafai et al., 2013). Unlike, teaching methods which emphasize the existence of a single answer to a problem, or a determined process to the solution, methods that support making, tinkering, coding and play emphasize on the significance of the process, rather than the result. Also, such way of thinking can promote interdisciplinarity amongst the STEAM domains (Science, Technology, Engineering, Arts, and Mathematics), the importance of which has been underlined by many scholars (e.g., Jin, Chong, & Cho, 2012).

The movement of making, called "the maker movement" has gained enormous momentum during the last few years, as an active process of building, designing, and innovating with tools and materials for the production of shareable artifacts. Making is a learner-driven educative practice which supports learning, participation, and understanding (Vossoughi & Bevan, 2014). Making is a process of creating something (Hsu, Baldwin, & Ching, 2017), or "the act of creating tangible artifacts" (Rode et al., 2015, p. 8). Others describe making as a strategy in which individuals or groups of individuals are encouraged to create artifacts using software and/or physical objects (Papavlasopoulou, Giannakos, & Jaccheri, 2017).

Tinkering, as a part of making (Vossoughi & Bevan, 2014) is a problem-solving technique and learning strategy, which promotes a practice of improvement and it is associated with experimentation and "trial and error" methods (Krieger, Allen, & Rawn, 2015). As Martinez and Stager (2013) argued, making and tinkering have evolved as a playful approach to solving problems through direct experience, experimentation and discovery. Programming, coding and physical computing are considered as making activities (Hsu et al., 2017) as they allow students to build and rebuild their artifacts (namely their robot), make the program design, code and debug.

Computational-making has been coined by Rode et al. (2015) to describe a combined set of skills that should be taught in STEAM education, namely computational thinking, aesthetics and creativity, visualizing multiple representations, understanding materials, and constructing (Rode et al., 2015). In other words, computational-making can describe making activities which require computation thinking skills and combine crafts with technology.

Play, as a dynamic, active and constructive behavior is naturally infused in all programming, making and tinkering activities. The playful nature of such activities promotes learner's interest (Ioannou, 2018; Vossoughi & Bevan, 2014). According to Martin (2015), learning environments organized based on making and tinkering settings are motivating and can support engagement and persistence and identity development.

Making, tinkering, coding and play activities might be seen as a relatively new practice in education, yet its theoretical roots are set in Papert' s constructionism (Jones, Smith, & Cohen, 2017), which builds upon Piaget's constructivism. Piaget defined knowledge as an experience that can be built through the interaction of the learner with the world, people and things (Ackermann, 2001) which is the experience that *making* offers to the learner. Similarly, Papert's theory of constructionism asserts that people construct internal knowledge when they design and build their own meaningful artifacts (Papert, 1980). Making is also linked to Vygotsky's social constructivism in that it can support learning and cognitive development through children's interaction with others whilst sharing knowledge (Nussbaum et al., 2009).

Although a few researchers have recently focused on the value of making, tinkering, coding, and play in learning (Krieger et al., 2015; Hsu et al., 2017; Martinez & Stager, 2013), a synthesis of this work is currently missing, creating an unclear path for future research in this area. A recent review of research in the making field was

presented by Papavlasopoulou et al. (2017) but authors focused on making studies in extracurricular contexts only. The present review aims to summarize research findings, published from 2009 to 2018, on learning outcomes promoted through making, tinkering, coding and play in formal and non-formal education. The following research questions (RQs) are addressed:
RQ1: What types of learning outcomes can be derived from computational-making-enhanced activities?
RQ2: What research methods and research design are being used?
RQ3: What types of learning contexts for computational making are being used?

2. Methodology

2.1 Selection of Studies

The subject's range was wide enough, as we searched for studies published in academic journals concerned with making, tinkering, coding and play in education. First, we conducted a search in the following electronic databases: ERIC, JSTOR, ScienceDirect, Taylor and Francis Online, Scopus in additional to Google Scholar using the keywords "making", "tinkering", "coding" and "play" (and/in) "education", whilst restring the dates range to 2009-2018. The search initially resulted in a total of n=3116 manuscripts.

By reading all the abstracts, we filtered the manuscripts using three criteria: (1) the study should be empirical. All studies that gathered empirical evidence through quantitative (e.g. surveys) or/and qualitative methods (e.g. interviews, focus groups, experiments) were included. Studies with no empirical findings, including reviews and theoretical perspectives were excluded (e.g., excluded review paper by Papavlasopoulou, 2017), (2) the study should involve computational-making-enhanced activities, as defined in the introduction of this work (i.e., evidence of "computation"). Studies referred to making activities without any computational elements were excluded (e.g., a study conducted by Alekh et.al., 2018), (3) the study should present learning outcomes, including outcomes on conceptual knowledge, attitudes and skills. Studies with no explicit reference to learning outcomes were excluded (e.g., Cohen, Jones, & Smith, 2018). After applying the above-mentioned criteria, we concluded with 57 manuscripts.

2.2 Categorizing the Studies

We thoroughly read the 57 manuscripts and coded (i.e., open coding) the basic information derived from each work. A first round of open coding for learning outcomes was conducted, aiming to examine the types of learning outcomes derived from the computational-making-enhanced activities (RQ1). Based on evidence from 15% of studies, we identified three major categories of learning outcomes namely, content knowledge outcomes, attitudes, and 21^{st} -century skills; these categories were then used for coding the rest of the studies. In a second round of coding, we coded for the types of research methods used (RQ2); in this case, we categorized the studies as qualitative, quantitative or mixed research methods whilst we recorded the sample size and age of the participants. Last, in a third round of coding we coded for formal and non-formal/informal learning context in which the computational-making-enhanced activities took place (RQ3). The coding was done by two researchers (authors) working closely together.

3. Findings

3.1. Learning Outcomes

The empirical findings on learning outcomes were organized in terms of content knowledge, attitudes, and 21st -century skills. Some of the studies reported outcomes in more than one category.

Content Knowledge. As P21 Framework (Partnership for 21st Century Learning, 2015) states, content knowledge refers to key subjects, such as science, mathematics, economics, arts, geography, world languages etc. Learning of programming or other computer science knowledge is also coded in this category. The results demonstrated that computational-making-enhanced activities were mostly linked to knowledge gains in programming and computer science. Fewer studies were concerned with science and engineering or arts and literacy. Major findings about knowledge gains are summarized in Table 1 and briefly discussed below.

To provide an example, in the study of Blikstein (2013) middle- and high- school students experienced digital design fabrication in FabLabs in schools. The authors found that through making, students had the opportunity to come across several concepts in engineering and science in highly engaging and meaningful ways. Furthermore, Kafai, Lee, Searle, and Fields (2014), conducted a study in an e-textile computer science class with high school students; based on the analysis of project artifacts and interviews, the authors found that the experience promoted learning through making concerning circuitry and debugging. Students' engagement with simple computational circuits using e-textiles materials was also examined by Peppler (2013). This mixed-method research (pre and post-tests, surveys, interviews, journals, artifacts, and videotaped observations) took place in a summer workshop with children aged 7-12 years old and documented that students' understanding of key circuitry concepts was significantly increased through making. Another study with high school participants conducted by Searle, Fields, Lui, and Kafai (2014), indicated that learning with e-textiles helped the students create a link between coding and making that contributed to their learning in computer science. Last but not least, Burke and Kafai (2012) found that middle school students learned the fundamentals of both programming and storytelling through making and tinkering and emphasized the potential of the connection between coding and writing.

Table 1. Major findings about knowledge gains.

	Authors	Findings on knowledge gains
1	Denner, J., Werner, L., & Ortiz, E. (2012)	Underrepresented students learned concepts of programming and understanding software, that would prepare them for computer science courses.
2	Khalili, N., Sheridan, K., Williams, A., Clark, K., & Stegman, M. (2011)	Students designed accurate visual representations of the constructs and verbally describe the concepts (biology and neurological concepts).
3	Kafai, Y. B., Lee, E., Searle, K., Fields, D., Kaplan, E., & Lui, D. (2014)	Students learned about circuitry.
4	Fields, D., Vasudevan, V., & Kafai, Y. B. (2015)	Students learning to work with programming tasks.
5	Kafai, Y., Fields, D., & Searle, K. (2014)	Students learned programming.
6	Kafai, Y. B., & Vasudevan, V. (2015)	Students learned about circuitry.
7	Searle, K. A., Fields, D. A., Lui, D. A., & Kafai, Y. B. (2014)	Students learned to design and program the electronic artifacts.
8	Kafai, Y. B., Searle, K., Kaplan, E., Fields, D., Lee, E., & Lui, D. (2013)	Students learned computing concepts and practices.
9	Burke, Q., & Kafai, Y. B. (2012)	Students gained fundamentals of programming and storytelling.
10	Telhan, O., Kafai, Y. B., Davis, R. L., Steele, K., & Adleberg, B. M. (2014)	Students learned about programming.
11	Schneider, B., Bumbacher, E., & Blikstein, P. (2015)	Learning gains were improved when students built the human hearing (biology) system without guidance.
12	Qiu, K., Buechley, L., Baafi, E., & Dubow, W. (2013)	Students learned programming via making activities using the combination of Modkit and LilyPad.
13	Perner-Wilson, H., Buechley, L., & Satomi, M. (2011)	Students learned to create technology (electronics) and programming.
14	Franklin, D., Conrad, P., Boe, B., Nilsen, K., Hill, C., Len, M. & Laird, C. (2013)	Students gained competence with several computer science concepts.
15	Esper, S., Foster, S. R., Griswold, W. G., Herrera, C., & Snyder, W. (2014)	Students learned about computer science, math and programming.
16	Esper, S., Wood, S. R., Foster, S. R., Lerner, S., & Griswold, W. G. (2014)	Students understood basic programming.
17	Garneli, B., Giannakos, M. N.,	Students who managed to change the game code did

	Chorianopoulos, K., & Jaccheri, L. (2013)	not improve their performance in math post-test. (negative results)
18	Posch, I., & Fitzpatrick, G. (2012)	Children learned about emerging technologies (electronics).
19	Peppler, K., & Glosson, D. (2013)	Students had significant gains in understanding of functional circuits.
20	Litts, B. K., Kafai, Y. B., Lui, D. A., Walker, J. T., & Widman, S. A. (2017)	Gains in students' understanding of circuitry were noted.
21	Worsley and Blikstein (2014)	Principle-based reasoning was associated with better quality designs and better engineering mechanism's understanding.
22	Blikstein, P. (2013)	Via digital fabrication the students experienced learning gains in computation and mathematics
23	Hartry, A., Werner-Avidon, M., Hsi, S., & Ortiz, A. (2018)	Gains on STEM knowledge were noted.
24	Elkin, M., Sullivan, A., & Bers, M. U. (2018)	Knowledge gains about programming and engineering, literacy and science.
25	Bull, G., Schmidt-Crawford, D. A., McKenna, M. C., & Cohoon, J. (2017)	Students learned concepts about computer science, engineering and literacy.
26	Patton, R. M., & Knochel, A. D. (2017)	Gains in art education.
27	Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014)	Students learned concepts about robotics, programming.

Attitudes. Students' attitudes towards learning can be measured through assessment of the perceived levels of interest, challenge, choice, and enjoyment, which are dimensions linked to motivation and engagement. Self-efficacy is also an attitude concerned with perceived beliefs in the individual capacity for specific achievements. In line with findings by Vossoughi and Bevan (2014) and Martin (2015) about making and tinkering activities promoting learners' interest, most of the studies reported positive effects on students' attitudes (see Table 2).

An indicative study comes from Chu et al. (2015), conducted with elementary school students in 3rd, 4th and 5th grades. Students used arts and craft materials, and electronics components to build a theatre kit. The results indicated that *making* lead to more robust learning for children as they sought to acquire STEM-knowledge to make the technological things of their interest. Similarly, results from a study conducted by Posch and Fitzpatrick (2012) in four workshops in Vienna, suggested that *making* in a FabLab can increase students' interest about learning emerging technologies. Another study with children (between 4-11 years old) working in an informal science learning environment with their parents indicated that the STEAM learning through making and tinkering nurtured learning both in personal interest and in concepts learned, enhanced engagement, and reinforced previous knowledge and basic motor skills (Moriwaki et al., 2012).

Table 2. Major findings about attitudes.

	Authors	Findings on attitudes
1	Denner, J., Werner, L., & Ortiz, E. (2012)	Underrepresented students were engaged in the concepts of programming (engagement).
2	Harnett, C. K., Tretter, T. R., & Philipp, S. B. (2014)	The experience of making helped students improve their attitudes towards engineering.
3	Lane, H. C., Cahill, C., Foutz, S., Auerbach, D., Noren, D., Lussenhop, C., & Swartout, W. (2013)	The acceptance of challenges was increased.
4	Moriwaki, K., Brucker-Cohen, J., Campbell, L., Saavedra, J., Stark, L., & Taylor, L. (2012)	Participants reported personal interest about science.
5	Kafai, Y. B., Lee, E., Searle, K., Fields, D., Kaplan, E., & Lui, D. (2014)	More realistic and positive attitudes were noted.
6	Chu, S. L., Quek, F., Bhangaonkar, S., Ging, A. B., & Sridharamurthy, K. (2015)	Increased interest and engagement incidents occurred.
7	Searle, K. A., Fields, D. A., Lui, D. A., & Kafai, Y. B. (2014)	Positive attitudes and perceptions towards computing.
8	Kafai, Y. B., Searle, K., Kaplan, E., Fields, D., Lee, E., & Lui, D. (2013)	The making activities broadened students' perceptions of computing.
9	Qiu, K., Buechley, L., Baafi, E., & Dubow, W. (2013)	Increased comfort, enjoyment and interest in working with electronics and programming.
10	Mellis, D. A., Jacoby, S., Buechley, L., Perner-Wilson, H., & Qi, J. (2013)	Participants felt comfortable and confident when working with crafts.
11	Mellis, D. A., & Buechley, L. (2012)	Positive attitudes about electronics and laser cutting.
12	Jacobs, J., & Buechley, L. (2013)	Engagement and positive attitudes towards programming.
13	Qi, J., & Buechley, L. (2014)	Enjoyment, freedom and fluency to use the technology.
14	Wagner, A., Gray, J., Corley, J., & Wolber, D. (2013)	Mobile computing gave opportunities to provide powerful new context about motivation in computational thinking.
15	Burke, Q., & Kafai, Y. B. (2012)	Significant improvement in attitudes about computer science, computing, and mathematics.

16	Giannakos, M. N., & Jaccheri, L. (2014)	Enjoyment was reported during children's programming experiences, lot of incidence of.
17	Giannakos, M. N., & Jaccheri, L. (2013)	The activity's easiness and usefulness significantly affected students' intention to participate.
18	Garneli, B., Giannakos, M. N., Chorianopoulos, K., & Jaccheri, L. (2013)	Participants' intention to learn programming was increased, positive attitudes towards programming were noted, as well as engagement and fun with the activity.
19	Giannakos, M. N., Jaccheri, L., & Leftheriotis, I. (2014)	Results showed positive effects of happiness and the negative effect of anxiety.
20	Hartry, A., Werner-Avidon, M., Hsi, S., & Ortiz, A. (2018)	Students reported that the program had strong impact on learners' interest on STEM.
21	Wagh, A., Cook-Whitt, K., & Wilensky, U. (2017)	Tinkering with program code facilitated engagement with science.
22	Elkin, M., Sullivan, A., & Bers, M. U. (2018)	The children were all engaged in the making activities.
23	Zajdel, T. J., & Maharbiz, M. M. (2016)	Significant increase of students' self-efficacy.
24	Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014)	Kindergartners were engaged and interested in robotics, programming and computational thinking.
25	Lane, H. C., Cahill, C., Foutz, S., Auerbach, D., Noren, D., Lussenhop, C., & Swartout, W. (2013)	Significant increase in self-efficacy.
26	Kolko, B., Hope, A., Sattler, B., MacCorkle, K., & Sirjani, B. (2012)	Self-efficacy and identity were reported.
27	Chu, S. L., Quek, F., Bhangaonkar, S., Ging, A. B., & Sridharamurthy, K. (2015)	Self-efficacy and self-identity improved.
28	Qiu, K., Buechley, L., Baafi, E., & Dubow, W. (2013)	Making activities increased students' technological self-efficacy.

21st-century skills. For coding for 21st century skills, we adopted the Partnership for 21st Century Learning Framework (2015) which suggests three theme categories of skills: learning and innovation skills, information, media & technology skills, and life & career skills. This framework was previously followed by Harris et al. (2016) to collocate opportunities that tinkering experiences provide for developing 21st-century skills). Several types of 21st-century skills were reported in the 57 reviewed studies (see Table 3). Most of the studies reported skills from the first category (i.e., learning & innovation skills). In some cases, *making* appeared as a 21st-century skill itself.

To provide some examples, in Harnett et al. (2015), undergraduate students engaged in making activities demonstrating increased competence in problem-solving and project-planning activities. Also, a study with adults (Perner-Wilson, Buechley, & Satomi, 2011), demonstrated that the participants were able to construct personally meaningful artifacts and that the approach made the technology more understandable allowing them to leverage existing skills to learn something new. The study also revealed that handcrafting technology fostered the realization of personal artifacts and afforded novel designs through the process of making. In a research conducted with children, in five out-of-school workshops (Posch & Fitzpatrick, 2012), the researchers reported that 10-14 years old children were able to transfer learned skills and experiences in other projects.

Table 3. Findings on 21st-century skills

Learning & Innovation skills	
Problem-solving (and Project-planning)	Harnett et.al. (2014) Kafai et.al. (2014) Schwartz, DiGiacomo, and Gutiérrez (2015) Searle and Kafai (2015) Esper et.al. (2014) Sheridan et.al. (2014) Hartry et.al. (2018) Bers et.al. (2014)
Critical thinking	Kafai et.al (2014) Hartry et.al. (2018) Posch and Fitzpatrick (2012)
Collaboration – Co-operation Communication	Moriwaki et.al. (2012) Mellis and Buechley (2012) Giannakos and Jaccheri (2013) Blikstein et.al. (2017) Blikstein (2013) Hartry et.al. (2018) Elkin et.al. (2018) Bull et. al. (2017) Fields, Vasudevan and Kafai (2015)
Creativity	Kafai and Vasudevan (2015) Wagner et.al. (2013) Rode et. al. (2015) Hartry et.al. (2018)
Information, Media & Technology skills	
Technology-technical skills	Jacobs and Buechley (2013) Kolko et.al. (2012) Wagner et.al. (2013) Litts et.al. (2017) Chu et.al. (2017)

Making skills	Okundaye et.al. (2018)
Computational thinking	Rode et.al. (2015) Kafai & Vasudevan (2015) Bers et.al. (2014) Esper et.al. (2014) Peppler & Glosson (2013)
Information literacy skills	Bull et.al. (2017)
Life & Career skills	
Decision making Leadership Time management Presentation skills	Elkin et.al. (2018) Okundaye et.al. (2018)

3.2. Type of research methodology

In terms of methodology, 30 studies were qualitative, 20 were mixed-method studies and seven were quantitative (see Fig. 1). In terms of sample size, 23 studies involved fewer than 20 participants, 17 studies involved more than 21 but less than 50, six studied involved more than 50 people but fewer than 100, and another six studies involved more than 101 participants (Table 4). Most work has been done with middle school students; less work deals with younger or older learners (Table 5).

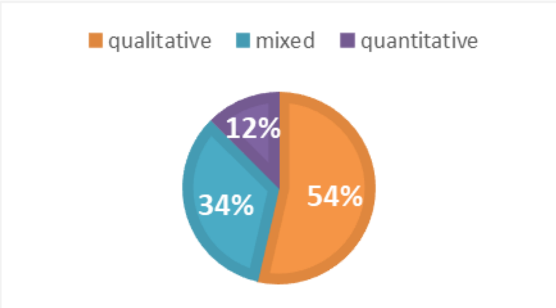

Fig. 1. Type of research method used in empirical studies

Table 4. Number of studies according to the sample size.

Sample size	Number of studies
< 20	23
21-50	17
51-100	6
101<	6

Do not mention	5
Total	57

Table 5. Number of empirical studies per to educational level.

Age	Number of empirical studies
Kindergarden	1
primary schools	10
secondary schools	26
primary & secondary	3
college/university	4
primary & secondary & university	5
Adults	3
children & adults	4
doesn't mention	1
Total	57

Educational context

Directly linked to the "maker movement", computational-making-enhanced activities have mostly taken place in informal and non-formal settings (e.g., libraries, science festivals, and museums). The general aim was to encourage students to design, experiment, create, explore and play with technological tools. Yet, since approximately 2016 (2018 only partially covered due to the time of conducting this review), there seems to be a growing interest in formal education (see Fig. 2), especially driven by K-12 educators (e.g., Bers et al., 2014; Chu et al., 2015; Fields et al., 2015; Wagh, Cook-Whitt, & Wilensky, 2017).

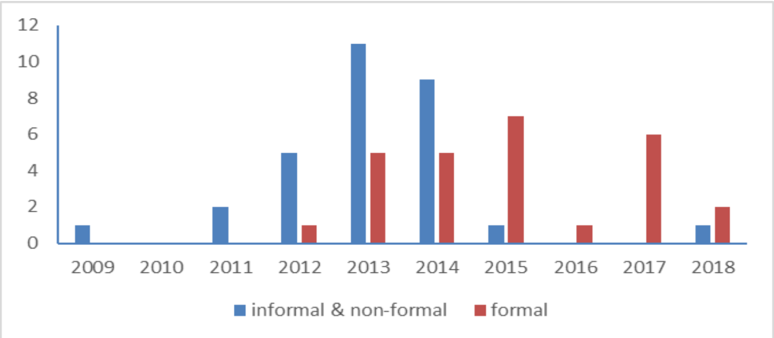

Fig. 2. Number of empirical studies throughout the last decade in formal and informal/non-formal education.

4. Discussion

The present review focused on making, tinkering, coding and play activities (i.e., computational-making-enhanced activities) for teaching and learning in formal and non-formal/informal learning settings. Below, we discuss the results of our review in relation to the initial research questions.

In terms of types of learning outcomes derived from computational-making-enhanced activities (RQ1), most of the studies in the review reported positive learning outcomes, namely outcomes on content knowledge, attitudes and skills. This is consistent with previous work arguing that making and tinkering are "potentially powerful contexts for learning" (Bevan et al., 2015, p.21). As Vossoughi and Bevan (2014) also noted, such activities open space for learners to pursue personal interests and can broaden participation for many students.

In terms of research methods (RQ2) the review revealed that most of the studies in this area (computational-making) tend to use qualitative or mixed methodology. As the investigation of learners' attitudes or skills is a quite complex issue, the use of qualitative measures was deemed more suitable in most studies (Kafai et.al., 2014; Harnett et.al., 2015) helping to understand issues of depth with computational-making. Yet, we now have enough evidence of the value of computation making, allowing for scaling-up the impact and measurement via quantitative studies. Quantitative methodology has only recently been used in computational making research, to document improvements in students' grades in formal education studies (e.g., Litts et. al., 2017).

Non-formal and informal contexts were most common for computational-making-enhanced activities (RQ3), especially in year 2013. That could be justified by the Maker Movement's appearance (2009-2013) as a new trend in museums, makerspaces, hackerspaces, fablabs, after-school clubs, etc. Yet, since 2016 only two studies were found to have been conducted in non-formal/informal contexts, in contrast to the 16 studies conducted in formal education. This indicates that educators might be interested in computational-making-enhanced activities, yet empirical evidence in curricular areas is lacking.

The review revealed some open issues that are worth exploiting in the future. First, while a growing number of efforts in computational-making-enhanced activities in formal education is being recorded in the last three years, the design of learning activities and overall classroom implementation are not explicitly addressed in these studies. There is an immediate need for educative content and teaching/learning procedures linked to curriculum goals. Second, computational-making-enhanced activities have been mostly linked to content knowledge's gains in programming and computer science. Less attention has been given to science and engineering or arts and literacy. Possibilities and gains in these other domain areas are worth exploring and assessing. Third, most studies have been done with students in secondary education. There seems to be a need for more studies covering the spectrum of leaners in K-12 and up to higher education. Finally, most of the studies appear to aim at testing of making, tinkering, coding and play as a method for teaching and learning, yet the learning goals and design of computational-making tasks are not explicitly discussed in the research manuscripts. Studies which inform the design of computational-making-enhanced activities in relation to curriculum goals and expected learning outcomes are in need.

5. Conclusion

The present review demonstrates that the contribution of computational-making-enhanced activities in education is significant. Almost all the studies in the review, have indicated positive learning outcomes, often in more than one category (knowledge, attitudes and 21st-century skills). The focus has been on programming and computer science whilst the field should be exploited in engineering, arts and literacy. During the last three years empirical work has shifted from informal/non-formal education to formal education. This indicates the growing interest of researchers and educators to integrate computational-making-enhanced in the school classroom. Yet, immediate action is needed to inform learning design and the design of computational-making-enhanced activities directly linked to curriculum goals. Most of the empirical research studies were conducted in secondary-school education, while more work is needed with younger or older leaders. Although a few researchers have recently focused on the value of making, tinkering, coding, and play in learning, a synthesis of this work is currently missing, creating an unclear path for future research in this area. Therefore, the review can have considerable value in guiding future researchers and practice in the field.

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