Entertainment, Engagement, and Education: Foundations and Developments in Digital and Physical Spaces to Support Learning through Making

Abstract:

Making is a relatively new concept applied to describe the increasing attention paid to constructing activities to enable entertaining, and engaging learning. Making focuses on the process that occurs in digital and/or physical spaces that is not always learning oriented, but enables qualities such as problem solving, design thinking, collaboration, and innovation, to name a few. Contemporary technical and infrastructural developments, such as Hackerspaces, Makerspaces, TechShops, and FabLabs, and the appearance of tools such as wearable computing, robotics, 3D printing, microprocessors, and intuitive programming languages, posit *making* as a very promising research area to support learning processes, especially towards the acquisition of 21st-century learning competences. Collecting learning evidence via rigorous multidimensional and multidisciplinary case studies will allow us to better understand and improve the value of *making* and the role of the various digital and physical spaces. Drawing from our experience with a recent workshop that used making as a pathway to foster joyful engagement and creativity in learning (Make2Learn), we present the developments, as well as the four selected contributions of this special issue. The paper further draws attention to the great potential and need for research in the area of *making* to enable entertaining, and engaging, and learning.

Keywords: Maker movement; learning technologies; entertainment technologies; creativity; knowledge construction; technological fluency; constructionist

1. Introduction

Making to enable entertaining, and engagingt learning has recently gained significant attention. Making is a broad concept that focuses on the process by which an individual can become a creator of things—a "maker." The philosophy behind making is not new, since Seymour Papert's Constructionism and "learning-by-making" principles have been available for more than 25 years (Papert & Harel, 1991). However, contemporary technical, infrastructural, and social developments—such as the appearance of various making spaces (e.g., FabLabs, Makerspaces), tools with diverse making affordances (e.g., 3D printing, microprocessors), and the acute need to ensure that future citizens and workers are fully prepared for a global economy and able to master 21st-century skills (e.g., critical thinking, innovation skills)—posit making as a highly promising research area to support learning.

Today, making is supported by a global community of innovators, designers, engineers, artists, programmers, hackers, tinkerers, and so on—people who share a vision related to the importance of making in empowering future inventors, innovators, and people who are going to change the world. If making concepts are designed properly, they can allow young people to constructively learn through their failures or successes, in a felicitous but also protected environment. By taking into account the recent advances of digital environments, entertainment technologies, manufacturing equipment, and community spaces, young people can benefit from diverse opportunities to experience making in an engaging, joyful, and pedagogically appropriate manner (Giannakos et al., 2015). Making in education is growing enormously, with recent research initiatives including a special issue on digital fabrication in education in the *International Journal of Child–Computer Interaction* (Iversen et al., 2016) and the launch of the FabLearn (Blikstein, 2013) community, to mention few. However, *from current research, it is difficult to tell which aspects of environments, engaging technologies, applications, equipment, and practices can have a positive impact in making.*

The current drive in many countries to teach design and technology competences to all has the potential to empower and support *making* as a creative, joyful, and problem-solving concept. Problem-solving, coding, and design have become an integral part of K-12 curriculum, as the Common Core Standards, the Computer Science Teachers Association (CSTA), and the International Society for Technology in Education (ISTE) standards have been widely applied (ISTE/CSTA, 2011). For instance, problem-solving and coding is considered a new literacy, and has been integrated into the school curriculum in many countries, such as Estonia, Finland, Israel, South Korea, and the United Kingdom, to name a few. Nowadays, more and more governments are seeking to teach 21st-century skills to all and support young students in creative and problem-solving tasks (Hubwieser et al., 2014).

Initiatives such as those for design thinking in K-12 education by d.school[1], for digital fabrication in education by FabLearn Labs[2], as well as grassroots education initiatives such as the Design for Change global movement[3] provide environments for invention, creation, discovery, and sharing. The contemporary movement for Makerspaces, Hackerspaces, and FabLabs, as well as initiatives pertaining to the world's most prominent research infrastructures (e.g., CERN's IdeaSquare[4]), bring people together to generate new ideas and work on conceptual prototypes in an open environment, towards socially and globally relevant new product ideas and innovation.

People should discover knowledge, rather than receiving it passively (Papert, 1980). Contemporary curricula, like that of the ACM/IEEE Task Force (ACM/IEEE-CS, 2013) emphasize the importance of developing and mastering problem-solving and design skills integrated with real-world, group-based construction learning activities. Although there is a growing body of research in the area (Papavlasopoulou et al., 2017), *there is still limited evidence on how to design, scaffold, support, and integrate making activities in order to achieve rich learning experiences*.

A number of challenges arise in ensuring that procedures, tools, and environments embody appropriate progression and engender motivation and joy. Gathering evidence of learning and reflecting on the different concepts of *making* to support the learning process is important to

[1] http://www.k12lab.org
[2] https://tltl.stanford.edu/project/fablearn-labs
[3] http://www.dfcworld.com
[4] http://ideasquare.web.cern.ch

portray the overall picture *making in education* encompasses. Current research on *making* is largely focused on describing the phenomenon in the form of case studies, or on discussing societal and technological developments, rather than focusing on learners' experience and how to enable engaging, and joyful, learning. There is therefore a need to *provide insights on how making can help us to advance current learning practices*.

2. Objectives

In order to employ *making* as a powerful learning concept, care should be taken to examine its impact on the learner experience. The overreaching objective of our special issue is to explore how *making* can improve the potential of current practices to enhance the learning experience by motivating and engaging students. Drawing from our experience during a workshop that used making as a pathway to foster joyful engagement and creativity in learning (Make2Learn) at International Conference on Entertainment Computing (ICEC) 2015 in Trondheim, we attempt to portray research developments through the following five objectives:

- O1. What *tool affordances* can help us to better support learning through making experiences?
- O2. Is any type of *content* more appropriate than others for learning through making experiences?
- O3. What *practices and pedagogies* can be (particularly) supported by learning through making?
- O4. What *assessment* can be implemented in learning through making?
- O5. What are the *intended competences/outcomes* in learning through making?

3. Learning through Making

The main objective of the Make2Learn workshop was to develop a critical discussion about the well-established practices and technologies of making, and expected outcomes of putting them into practice under different environments, such as Hackerspaces, Makerspaces, TechShops, FabLabs, etc. This will allow us to understand which aspects of making—such as environments, engaging technologies, applications, equipment, and practices—have a positive impact on the learning experience. The five aforementioned objectives were used to guide the discussion.

In order to collect the different opinions and categorize them, we decided to employ the affinity diagram technique within the different focus groups conducted in the workshop. Using a focus group enables a wide variety of collective views to emerge, and often leads to results based on a consensus among participants (Maguire & Bevan, 2002). The affinity diagram technique is used to organize ideas and information from a large amount of data (Maguire & Bevan, 2002). The tool is commonly used within project management and ethnographic studies as it allows large numbers of ideas stemming from brainstorming and other qualitative data to be sorted into groups for review and analysis based on their relationships. The main steps of the technique are: (1) record each idea as a note, (2) look for ideas that seem to be related, and (3) sort notes into groups.

In the 2015 Make2Learn workshop (which was jointly organized with the 14th ICEC in 2015) (Giannakos et al., 2015) 20 participants were divided into four focus groups. The participant sample consisted of:

- three directors of education with experience in making activities (i.e. working in organizations such as science museums and making labs in schools),
- five researchers (PhD students) in the area or interaction design and design thinking in education,
- three senior researchers (postdoc) in the area of making technologies in education,
- four instructors in higher education with experience in making activities, and
- five educators with experience in making activities in K-12 schools.

The participants of the workshop focus in three areas, named, design, technology or education. There was also a variation in their experience; going from 2-3 years of experience (e.g. PhD students) to more than 20 (e.g. professors, directors), with responsibilities in various settings (e.g., formal, informal learning) and contexts (e.g., industry, university, museums, K-12 schools). Participants were from various countries like, Denmark, Finland, the Netherlands, Greece, Italy, with the majority being from Norway. Most of the participants were active in the international arena with experience from various countries and contexts.

The focus groups were designed to be as heterogeneous as possible, and consisted of five participants each. The focus groups worked with the five aforementioned objectives and used post-it notes to construct affinity diagrams and provide information on each of the seven aspects. Different groups operated different practices in order to map their ideas with the best possible for them way; for instance, some teams discussed a lot before the development of affinity diagrams and others draw some sketches (e.g., see figure 1). This was an iterative process that consisted of adding or removing post-it notes until a consensus was reached (e.g., see figure 2). The affinity diagrams were completed and were then presented and discussed with the other focus groups. Table 1 summarizes the outcome of this process.

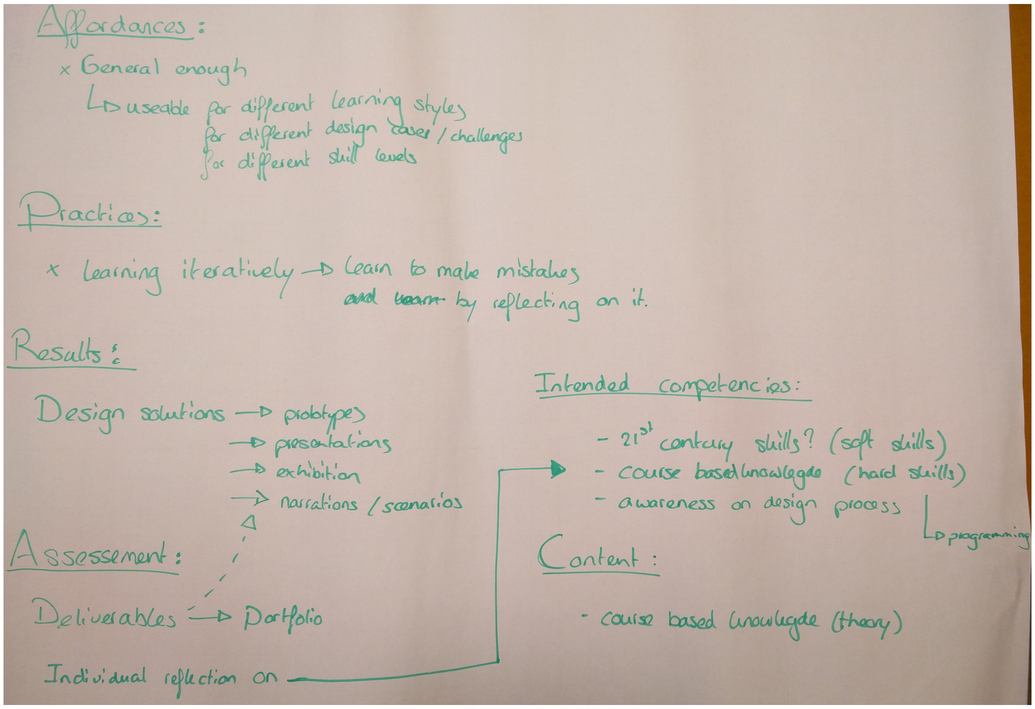

Figure 1: *Different strategies were used from the teams to map their ideas, for example one group started working with paper and marker before going to post-it notes*

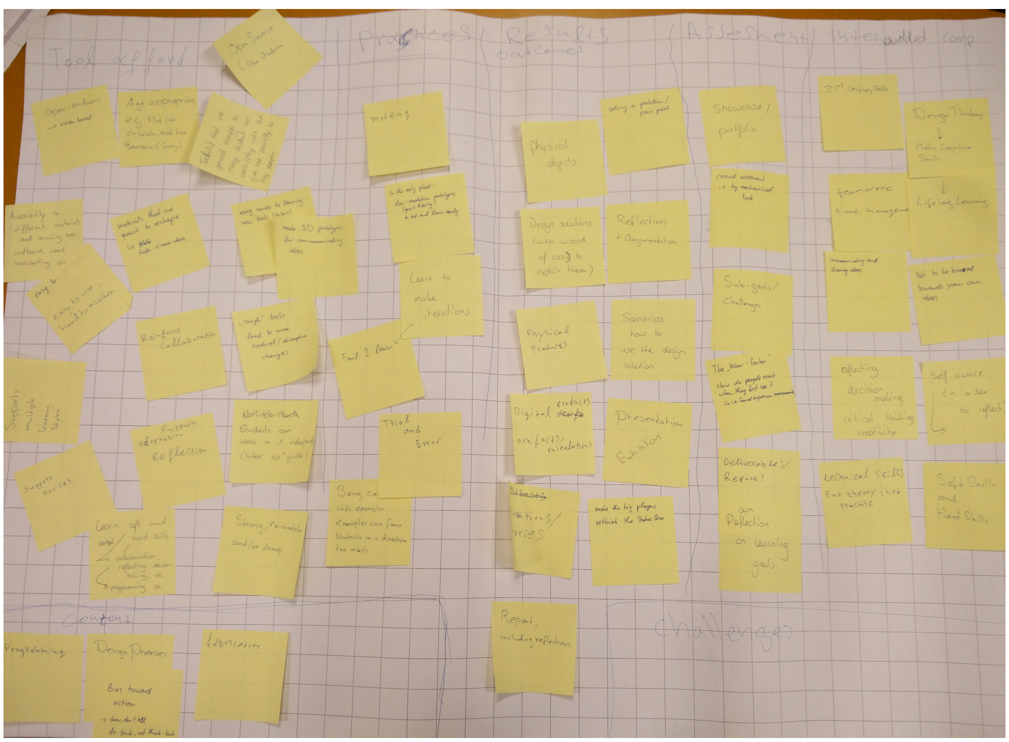

Figure 2: *A snapshot towards the construction of affinity diagrams: During the discussion, participants were writing their ideas in post-it notes and trying to categorize them within the five objectives*

Table 1: *Outcomes of the affinity diagram process within focus groups*

Tool Affordances	Content	Practices, Pedagogies, and Focuses	Assessment	Outcomes	Intended Competences
- Robust and reusable - Empower both soft (e.g., collaboration, reflection, decision making) and hard (e.g., programming, tinkering) skills - Intuitive design (e.g., support novices) - Low floor/high ceiling—easy-to-learn, hard-to-master affordances - Quick to reshape (i.e., malleable) -Open source tools - General enough and usable for (i) different learning styles, (ii) different design cases/challenges, and (iii) different skill levels - Supportive of adaptation	- Design processes and concepts - Fabrication - Hard-to-tell/ easy-to-show concepts - Abstract knowledge - Concepts need several iterations to be learnt (e.g., design, mechanical engineering, programming)	- Trial and error - Modding and hacking - Low fidelity/quick prototypes and iterative testing/learning - Learning how to make prototypes to communicate ideas - Learning from both successes and failures - Avoiding forcing students in a certain direction (e.g., by using certain focus examples)	- Showcase/portfolio - Students' own (self-) reflection/assessment of learning goals - Crowd assessment (i.e., via mechanical tank) - Artifact-based assessment - Deliverables, reports, and roadmaps to support assessment	- Physical objects - Design solutions (e.g., with Wizard of Oz explaining them) - Scenarios (e.g., how to use the design solutions) - Installations/exhibitions - Narrations/stories - Prototypes	- 21st-century skills (soft) - Course-related (hard) knowledge (e.g., programming) - Awareness of design and problem-solving processes - Communicating and sharing ideas; teamwork and time management - Exploring learning materials (through intuitive guidance) - Adaptive design (progressive enhancement) and adaptation affordances

Capturing and mapping ideas from experts is a difficult task, and the method followed has certain limitations. We believe that the categorized information (Table 1) can serve as useful guidance in future discussions and research into making activities to enable entertaining and engaging learning. According to the extensive discussions and idea collection/categorization conducted during the workshop, we think that these five dimensions can serve as a reference point to assist future research on how to improve the value of *making* and the role of the various spaces, technologies, and practices in this direction.

Most of the literature (Papavlasopoulou et al., 2017), but also the discussions during the workshop depict into the fact that new set of societal needs, new technologies and new ways of using knowledge have emerged as a necessity during the last years. Currently, educators have started leveraging a variety of new technologies – such as Alice, Scratch, Greenfoot, and Kodu – which can set challenging and dynamic learning experiences in educational contexts. Since Papert's (1980) constructionist framework was created, different practices, models, and strategies have represented new ways in which computers can be used in student-centred design learning experiences.

During the last years, we have seen systems utilizing the described from the participants' affordances to support learning. For instance, low floor/high ceiling affordances is the cornerstone of Scratch (Resnick et al., 2009). Moreover, Scratch Junior was developed to support young novices with an intuitive design. Other tools like, LilyPad Arduino and 3D printing were designed to empower both soft (e.g., collaboration, reflection, decision making) and hard (e.g., programming, tinkering) skills (Buechley et al., 2008).

As for the intended competences, the participants discussed that students need to acquire skills and digital competences in accordance with 21st-century needs[5]. For instance, computational thinking, problem-solving, design processes, fabrication and coding are integral content areas of making in education. Thus, the content needs to support the identified intended competences. As for the practices, pedagogies and focuses, following Papert's constructionism (1991), which states that students can learn deeply during activities that require them to apply the knowledge obtained by executing tasks. The participants described various forms of instruction and pedagogies to support making in education, such as modding, hacking, prototyping, learning by doing, learning by designing, and project-based learning, to name a few.

The produced outcomes can be both tangible and intangible objects. For instance, the participants mentioned that outcomes can be physical objects like 3D printings and constructions, design solutions like paper prototypes and sketches, scenarios or use cases, installations, narrations, stories, games and other programming applications as well as various combinations of the above. Making practices in education have also changed the way we assess our students. Traditional test-based assessment doesn't reflect neither the making practices not the expected competences (e.g. fabrication, problem-solving); thus, the participants highlighted that making should focus in different assessment practices like, showcase/portfolio assessment, artifact-based assessment and

[5] Framework for 21st century learning: http://www.p21.org/our-work/p21-framework

project deliverables and reports to name a few. This also entails that there is a need for different support mechanisms, like, assessment rubrics.

4. Conclusions and Future Directions

The advances of digital environments, technologies, manufacturing equipment, and community spaces offer diverse opportunities for making practices to facilitate learning, especially when supported by engaging and joyful entertainment technologies and designed in an appropriate pedagogical manner. During the last years, we have seen various hardware and software supporting students to conduct scientific explorations (Chu et al., 2017), create e-textiles, jewelries and wearables (Buechley & Eisenberg, 2008), design simulations and videogames (Torrente et al., 2014), design and code robotic systems (Takacs et al., 2016), create sophisticated games and various programming applications (Kafai & Vasudevan, 2015; Giannakos, Jaccheri & Morasca, 2013). Thus, the plethora of technologies and practices developed during the last years to support making in education enhances the traditional learning with new expressive qualities. Logo-based programming environments changed the way we teach geometry by adding algorithms to students' bodily movements (e.g., turn right, turn left). Construction kits added "behaviors" to materials, like "light up if dark" or "follow the line". Those qualities make possible for making to invent new forms of expressiveness and utilize technology to support 21st century education.

Although, the current drive in many countries to teach 21st-century skills to all has potential to empower and support *making* as a creative, joyful, problem-solving, and critical-thinking task; there are a number of challenges in ensuring that procedures, tools, and environments embody an appropriate progression and engender motivation and joy.

To explore the future of technologies, tools, and various spaces in which to foster engagement and creativity in learning, we seek to promote interest in well-established tools and practices of the maker movement, along with expected outcomes of putting them into practice in different environments, such as Hackerspaces, Makerspaces, TechShops, FabLabs, and so on. This will allow us to better understand and improve the value of making, as well as to accelerate the process of disciplinary convergence. We aspire to bridge computer science, learning science, design, HCI, and related disciplines to encourage ambitious research projects that could yield potent tools for many students to use. Make2Learn was implemented with an aim of collecting high-quality studies around this topical area, in order to illustrate what the next generation of technologies, environments, spaces, and practices might look like. In particular, from Make2Learn discussions and our own experience, we believe that the following elements are vital for the future research agenda in the area:

1. *Accelerate research on making* by proposing ways to enhance interest in and synergies among researchers, educators, students, policymakers, and designers.

2. *Promote rigorous multidimensional and multidisciplinary methods and implement robust experimentation strategies and metrics* for in-depth longitudinal case studies.

3. *Design tools, kits, and spaces for individuals* to promote "low-floor" (easy-to-start) and "high-ceiling" (to create increasingly complex projects over time) opportunities for young people.

4. *Develop meaningful, affordable, and intuitive making experiences* to enable students to more actively take part in learning through construction activities.

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