Design and Technology Education: An International Journal

22.3

Creativity Assessment in the Context of Maker-based Projects

Benjamin Lille, Université Laval, Canada
Margarida Romero, Université Nice Sophia Antipolis, France

Abstract

Creativity is a key competence in 21st century education. Among the active learning pedagogies which aims to develop creativity, learning by making is an emerging approach in which the students are engaged in the co-creation of a shared artefact. In this study, we aim to analyse the creativity competency through a maker-based projects. #SmartCityMaker project aims to design and to build a smart city model. We analyse the creativity competency through a rubric-based assessment and discuss the opportunities of creative project-based challenges in the development of creativity in maker-based projects in Higher Education.

Key words

creativity; higher education; maker; teaching practices; project based learning

Creative education

Creativity is a key competence for facing the social challenges of post-industrial knowledge societies (Garrison, 2011) and is increasingly considered as an important competence in relation to the current and future society (De Bono, 2015; Florida, 2014; Sternberg & Lubart, 1995). Creativity could be observed when participants engage in the design of a new, innovative and pertinent way to respond to a potentially problematic situation, which is valued by a group of references in a context-specific situation (Csikszentmihalyi, 1996; Franken & Bauers, 2002; Romero & Vallerand, 2016). Despite the importance of creativity and collaboration in 21st century society (Hesse, Care, Buder, Sassenberg, & Griffin, 2015) and the increasing differences between the “creative class” and the other citizens (Florida, 2014), creativity in educational settings is still not being considered as a key priority by some educational actors and is considered less important than disciplinary content (Willett, Robinson, & Marsh, 2012). While creativity is being included by policy makers (Shaheen & others, 2010) in K-12 curriculum, most teachers are often still focusing on knowledge acquisition (Boutonnet, 2015; Davies, 2004; Molin & Grubbström, 2013) rather than on competency development such as creativity. Creativity is also still not part of the daily academic discourse (Kleiman, 2008) in higher education (HE). One reason that could explain the scarcity of studies on creativity in HE is that creativity poses a challenge to the HE organisational system that often relies on compliance and constraint, but also the richness and complexity in the way academics and teachers perceive creativity (Kleiman, 2008) and design-based learning (Kimbell, Stables, & Sprake, 2002). Jahnke, Haertel and Wildt (2017) observe that there is no unique understanding of what creativity is and highlight HE professors’ view of creativity as something that is subjective and as a process that is mostly individual. Despite the multifold aspect of creativity, they are features of creativity that are often mentioned by scholars when it comes to defining it, such originality, novelty and relevance. These different creativity traits are often considered in individual context, as a process and a product obtained by the creative process of a subject

(Sternberg & Lubart, 1995). In the literature, creativity has been mainly developed and analysed by individual activities (Romero, Hyvönen, & Barberà, 2012), which are often limited in their scope of supports to express learners' creativity. In this paper, we consider creativity as an individual or collaborative reflective iterative process (Runco, 2014) that aims to design a new, innovative and pertinent way to respond to a potentially problematic situation, which is valued by a group of references in a context-specific situation (Csikszentmihalyi, 1996; Franken & Bauers, 2002; Romero & Vallerand, 2016a). The creative process leads the learner to explore several new solutions to a problem, to use inspirational work in order to orient thinking and finally to select a solution while considering the context of the problematic situation. Therefore, creativity in educational contexts is defined by the balance residing between divergent, convergent and associative thinking. Exploring new and purposeful solution relies on students' ability to think divergently (Guilford, 1962), by generating original possible solutions and by thinking convergently in establishing congruencies between these new solutions. Thinking creatively and finding original ways to solve problems often relies on learners' competency to recognise the value of existing praised solutions in the same or in a different context that can inspire finding a new solution. Combining two different elements coming from different contexts is defined by associative thinking (Benedek, Könen, & Neubauer, 2012; Howard-Jones, 2002). Assessment of the new-found solutions is a process than can be led individually and collectively, but also by a member outside of the creative process possessing an authority (or credibility) in the domain. We also stress the importance of iteration in the creative process. After being assessed for the first time, it is important to allow time for learners to adjust components of the solutions that were not adapted to the context. We therefore argue that creativity in education echoes some key principles of design thinking. Creativity also depends on the convergence of several factors such as disciplinary competencies, process-relevant factors guiding the direction and progress of the creative process as well as social and environmental features that ensure a supportive environment that enables students to be confident, motivated and able to take risk (Rutland, 2009). As educational contexts do not always allow for creativity development to be the main learning goal, we also wish to stress the importance of the creative margin in the results and in the process. For example, educational context sometimes calls for every learner to produce the same result, yet by a different process while sometimes it is the process that is mandatory, but each result can be unique. This definition of the creative process triggered by a problematic situation echoes Vygotsky's double stimulation concept where learners collectively engage in overcoming critical conflicts by using mediating cultural artefacts in order to create a solution that emancipates them from this problematic situation (Vygotsky & Rieber, 1997) by feeling confident to take risks. Considering pre-existing literature on creativity in educational context, the scarcity of studies on creativity in HE as well as the pre-eminence of knowledge acquisition over competency development like creativity, we therefore wish to address these important issues by investigating how creativity can be developed in HE without jeopardising acquisition of content-related knowledge? This study is part of the #CocreaTIC Participatory Action Research (Whyte, 1991) project that aims to offer a better and practical understanding of 21st century competencies development such as creativity with digital tools.

Maker-based education and creativity

Taking into perspective creative computing (Brennan, Balch, & Chung, 2014) and maker culture approaches (Dougherty, 2012; Peppler, Halverson, & Kafai, 2016) developed in an increasing number of formal and informal settings in recent years, we consider creativity as a process that could be supported not only by computers but also by diverse digital technologies, such as robotic components. Learning-by-making, which drives the Maker movement, is a creative computing approach aiming to engage the learners in the construction of digital and tangible artefacts through the use of technologies (Martin, 2015). Maker activities provide an opportunity for the development of interests, identity, and content area knowledge (Martin 2015). Through maker-based project activities, participants can be engaged in constructionist activities based on developing an idea and then designing and creating an external representation of that idea (Y. B. Kafai & Resnick, 1996; Papert & Harel, 1991; Sheridan et al., 2014). According to (Mclaren, Stables, & Bain, 2006): “the articulation and externalisation of personal and creative thinking from the ‘minds eye’ to a tangible outcome is a central issue when engaging in design activity”. Maker-based education could therefore be considered as a form of design-based learning in which the learners are engaged in modelling and prototyping a physical, and often digital-enhanced, artefact. According to Vossoughi and Bevan (Vossoughi & Bevan, 2014), there are three major impacts that making has had on student development: fostering and supporting students’ participation in science environments, supporting academic/disciplinary development, and creating communities of learners. While learning by creating artefacts, learners can also develop 21st century competencies, such as creative problem-solving (Katterfeldt, 2014). Maker activities are not focused on digital technologies but on design-based approaches of creating an artefact to provide a solution. In makerspaces or fablabs, the technology is not the focus but rather a tool for creating and innovation. Technological tools are pedagogically relevant when they offer added value for the learner educational experience. Educational robotics, for example, provides the learner the opportunity to work in an interdisciplinary context where coding, engineering, mathematics, design, and science concepts can be learned (Eguchi, 2014).

Maker education is “an education approach that positions the student as an innovator with the responsibility to find solutions to relevant problems” (Wiebusch, 2016, p. 1). In maker education, the creative process is as, or even more, important as the final product (Gerstein, 2016). The importance given to the creative process in maker education could help address a problematic in assessing creativity: creativity assessment is often too focused on the outcomes than on the process (Mclaren et al., 2017). Maker activities are driven by the learner’s interest and can support curiosity and inquiry while creating with tolerance for failure and retrial and encourage peer collaboration (Oliver, 2016). The maker movement culture based on sharing, autonomy, iteration giving, participating and supporting (Barma, Romero, & Deslandes, 2017; J. D. Cohen, Jones, Smith, & Calandra, 2016) could facilitate the emergence of creative processes and outcomes. Making can contribute in empowering learners and develop a greater sense of possibilities to engage and shape their future (Agency By Design, 2015). Jankowska & Atlay, (2008) highlight the positive effects on student engagement that can be fostered by creative learning spaces such as the makerspaces or fablabs. Makerspaces are open to do-it-yourselfers of varied backgrounds and ages. Maker space activities that combine digital technologies with crafts and more traditional technologies such as a sewing machine can therefore require a variety of competencies and skills that can be attained through the collaboration of younger and older learners. Using maker spaces for joint projects requiring both experience-based and technological know-how could be an opportunity not only for different types of intergenerational learning but also for achieving the goal of inclusive design and the development of an innovator and creative mindset**.** Jefferson and Anderson (2017) highlight the potential of maker activities, both in formal and informal, learning contexts to foster creativity (Posch & Fitzpatrick, 2012), but also other key competencies for the 21st century such as collaboration and problem solving. Learning by making encourages learners to understand how technology works, rather than be satisfied simply consuming technology (Y. Kafai, Fields, & Searle, 2014). Learning by making activities therefore provides opportunity for learners to co-create with technologies which has been argued by (Romero & Laferrière, 2015) as a more advanced usage of ICT than simply consuming them. In maker activities, teachers usually serve as facilitators or learning guides by modelling, asking questions, collaborative play, and explaining how tools work (Brahms, 2014; Gutwill, Hido, & Sindorf, 2015), which corresponds to the teacher's role in other pedagogical strategies where the student is active. In order to help pre-service teachers integrate maker education in their teaching practices, Cohen (J. Cohen, 2017) stresses the importance of integrating maker activities in the pre-service teachers' curriculum to increase their self-efficacy relative to learning and teaching with maker technologies.

#SmartCityMaker (FabVille), a techno-creative project

The #SmartCityMaker is a research project that aims to develop learners' 21st-century competencies, such as creative problem-solving, by proposing a theme-immersed techno-creative project in which learners are engaged in a learning-by-making approach through co-designing and co-constructing pedagogical sequences exploiting a model of a city. #SmartCityMaker is a pedagogical sequence where technology is used to foster learners' design thinking (Bowler, 2014) by placing learners in a complex task that requires a high level of creativity. We consider that learners are required to reach a high level of creativity because they are asked to address a complex educational issue by creative use of ICT. For example, one team chose to address the issue of dysphasia in class by creating a pedagogical sequence that meets the needs of dysphasic children with creative use of ICT. #SmartCityMaker also adopts an approach that offers digital resources that are combined with a tangible model of a smart city.

Figure 1. Construction of the smart city model.

The combination of digital and tangible objects could offer an opportunity for learning through embodied cognition (Wilson, 2002) as learners are able to physically interact with the pedagogical artefacts. Wilson understands embodied cognition as "the idea that the mind must be understood in the context of its relationship to a physical body that interacts with the world" (p. 625). Indeed, knowing that learners have a limited working memory capacity, it is stressed that dividing the cognitive load imposed by the learning task through different subsystems of memory could prevent negative effects from cognitive overload (Baddeley, 1992, 2012; Chandler & Tricot, 2015). Moreover, gestures can help reduce cognitive workload, therefore, freeing resources from working memory load that can be used in order to create deep understanding (Chandler & Tricot, 2015; Glenberg & Robertson, 1999; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001).

Intertwining craft with digital artefacts could foster learners' engagement in complex programming concepts and practices that could help develop 21st century competencies such as creative computational thinking. As constructing a city model in the classroom and creating a pedagogical sequence are complex activities, it requires a certain number of sessions to be completed. In the first (few) sessions of the project, the #SmartCityMaker is constituted of activities, which are developed with a higher degree of teacher regulation. The first activities engage learners as city planners, and each small team should define the urban standards and the theme to design and build the building in their neighbourhood. Design thinking approach (Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013) is central to the conception and construction of their building model as learners need to respect individual and collective criteria, therefore complexifying the building activity and relying on creative problem solving. The models need to respect a specific scale, to be made in low-cost or recycled material, clearly express the team-chosen theme, to be solid enough so can be transported each week. The building process and results are first assessed in formative way to allow learners to modify components of their building that are lacking in coherence and creativity. In this initiation phase, students are organised in teams based on their level of confidence in the use of ICTs in order to ensure teams are homogeneous from this perspective. The first activities aim to develop team building (forming and storming) and the norming stage (Tuckman & Jensen, 1977). Norming is orchestrated through the urban rules definition task where teammates decide together how they will work as a team and what the urban rules of their neighbourhood in the #SmartCityMaker project are. Buildings are assembled within the team, and the different neighbourhoods are merged at the end of the second session of the course. The second part of the project is carried out in parallel through team-based projects by students. As previously mentioned, each team is required to address an educational issue that they may face in their career and to analyse it. They are then asked to design a pedagogical intervention considering Technology Enhanced Learning (TEL) possibilities. The students are then asked to anchor their techno-creative pedagogical sequence within the theme of the city model. Concretely, students could implement ICT in the city model in order to pedagogically exploit them. For example, one team developed a sequence where students would have to make robots circulate in the city in order to develop mathematics concepts. Subsequently, students are invited to discuss the educational limit of their activity and the potential transferability of the activity in another educational context. Figure 2 introduces the different phases and tasks within the #SmartCityMaker project, which combines both guided tasks and autonomous project-based responsibilities within a co-design and iterative approach (Bowler, 2014).

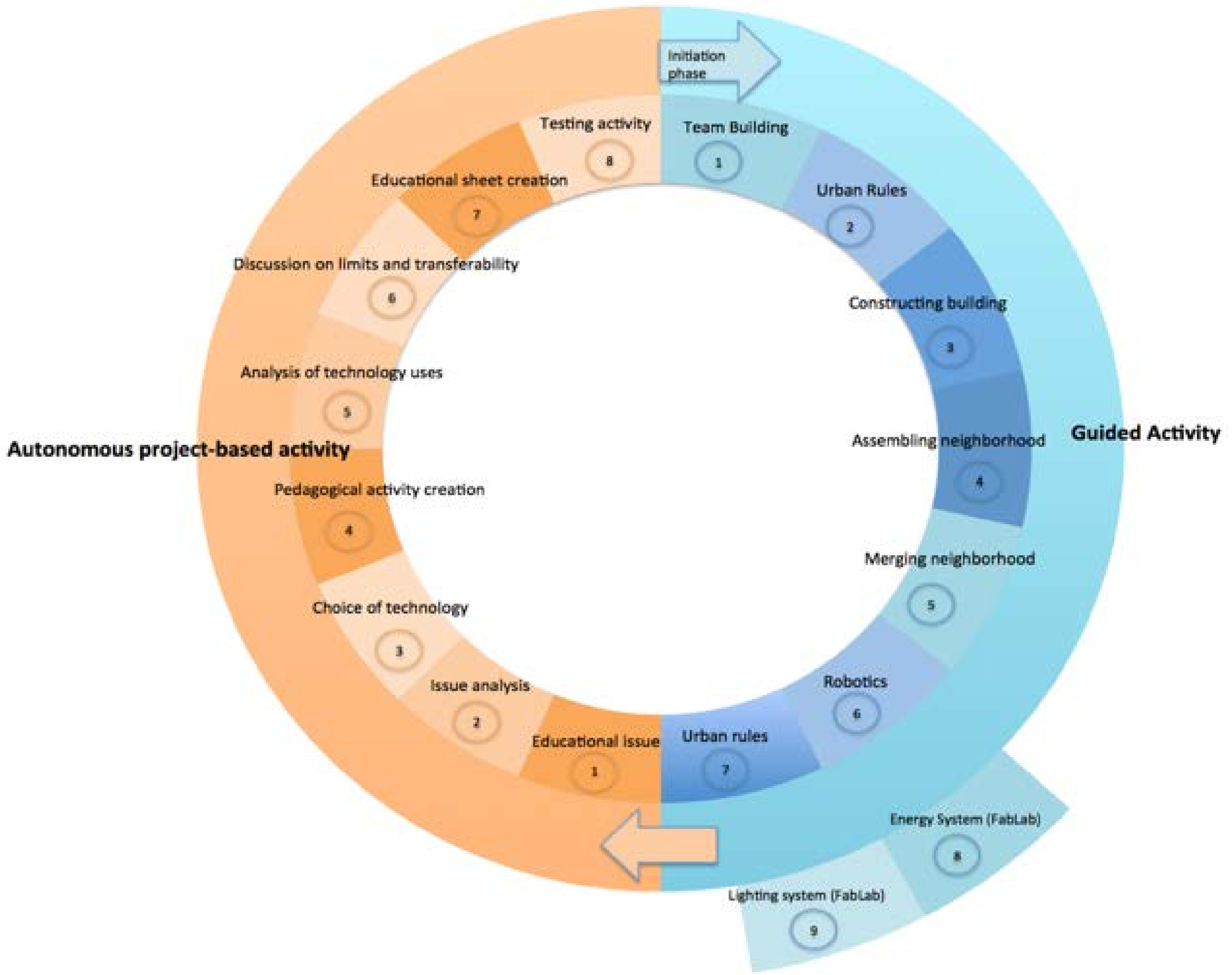

Figure 2. #SmartCityMaker iterative process

The city theme has been chosen by its potential to build on the city model through interdisciplinary projects. Cities are complex systems, which engage all the curriculum disciplines at different stages. From geography technics for being able to read and transpose a plan, to history and mathematics required to reconstruct a building, all the disciplinary objectives of the Québec curriculum (PFÉQ, Gouvernement du Québec, 2011) can be related to the city theme. Moreover, the concept of a smart city “as a city that uses digital technology, data analysis and connectivity to create value and address its challenges” (Feder-Levy, Blumenfeld-Liebertal, & Portugali, 2016). The smart city theme offers a large diversity of possible projects, which requires digital solutions to improve the problems identified by the students in their daily lives. Within the #SmartCityMaker class-based projects, students are invited to develop small team projects to integrate urban sciences, logistics, geography and history concepts as well as Science, Technology, Engineering, the Arts and Mathematics (STEAM). The city model can be a construct based on a real city, therefore offering different geographical issues to explore through the city’s construction or can also be an original creation designed from scratch by the learners. #SmartCityMaker values the use of ecological and recycled materials as well as the use of already used materials in the building model construction over the use of new materials. As (Tanenbaum, Williams, Desjardins, & Tanenbaum, 2013) argues, maker activity is determined by prevailing ethos of “making is better than buying. Furthermore, #SmartCityMaker also seeks to use low-priced digital resources alternatives with equal pedagogical value instead of expensive resources. Creating

#SmartCityMaker projects with affordable digital resources have the possibility to increase the transferability and implementation odds of such a project in disadvantaged areas.

Figure 3. #SmartCityMaker activity in Québec FabLab.

Collaborative research approach (Desgagné, Bednarz, Lebuis, Poirier, & Couture, 2001; Wiske, Educational Technology Center, & And Others, 1988) is valued through the #SmartCityMaker project. Pre-service teachers of Université Laval (Canada), primary and secondary level students from Québec at the fablab *EspaceLab* located at Bibliothèque Monique-Corriveau in Québec City, and volunteers with a high expertise on STEAM collaborate on the project. Collaborative research allows them to test and to prototype some of the #SmartCityMaker activities within the informal learning context of the fablab and then transfer it in a large-scale undergraduate pre-service course at the Higher Education context.

2. Methodology

2.1 Participants

The participants are pre-service teacher students divided in five different groups. All groups were studying a sixth-term course of a Bachelor of Education program for pre-service preschool and elementary school teachers (BEPEP) at Université Laval (Canada). A total of 198 participants (17 men and 181 women) were engaged in the #SmartCityProject within their compulsory course on educational technologies. The course 'ICT uses for preschool and elementary school' is a required course of 3 credits offered at the third year of the pre-service teachers programme. The first four groups attended the Québec city campus while the other one attended the Beauce campus.

2.2 Procedures

There is double perspective assessment of students" creativity in the course. The first one is an individual assessment based on the building process and the result of an urban building model while the second one is a team-based assessment of pedagogical creativity to produce a new and purposeful way to address an educational issue. Students were first asked at the first session to individually build an urban or rural building model for the following week. Their model could be an original creation or a creative replica of an existing building. Each student was assigned to a small team of three to seven students. Each team had been provided with four children's foam mat tiles. Their first activity as a team was to decide the urban rules for their neighbourhood. Teams were required to decide the building norms so that each unitary building model was compatible within the neighbourhood urban rules defined by the team. Urban rules included the model scale. For example, a team had decided to build their models on a scale where one centimetre of the model represented one metre in reality. While coordinating the activity, teams had to ensure that every building model fitted on provided foam mats. Each student was engaged to design and create a building according to the team urban rules as homework. During the second session, each student brought their building model in order to create and design their neighbourhood on the foam mat. Before assembling the building on the foam tiles, each team was asked to plan and draw a road within their neighbourhood and to interdependently coordinate their roads with other teams to ensure that all neighbourhoods were connected as a city. After the city model co-design, each team was asked to find an educational issue that interests them. After choosing their educational issue, students were asked to justify its relevance and analyse it by referencing scientific literature. Students then had to create an interdisciplinary pedagogical sequence that integrated collaborative and creative uses of digital technology that was going to be evaluated in a team-based assessment. The pedagogical sequence also had to revolve around the theme of the city so that elements could be physically integrated in the previously built city model. The city theme has been chosen by the potential for interdisciplinary projects to build on the city model. Cities are complex systems, which engage all the curriculum disciplines at different stages. From geography technic for being able to read and transpose a plan, to history and mathematics required to reconstruct a building, all the disciplinary objectives of the Québec curriculum (PFÉQ, Gouvernement du Québec, 2011) can be related to the city theme. Moreover, the concept of a smart city "as a city that uses digital technology, data analysis and connectivity to create value and address its challenges" (Feder-Levy et al., 2016, p. 2). The smart city theme offers a large diversity of possible projects, which requires digital solutions to improve the problems identified by the students in their daily lives. Exploiting a rich theme such as the smart city could serve as breeding ground for creativity development intertwined with curriculum knowledge acquisition. Subsequently, students were invited to discuss the educational limit of their activity and the potential transferability of the activity in another educational context. Finally, each team was asked to conduct an in-class pilot of their pedagogical sequence so that they can get feedback from teachers and peers based on actual practice. The process from abstract research to concrete pedagogical practice echoes Davydov's concept of "ascending from the abstract to the concrete" that is used in activity theory. (Davydov, 1988; Engeström, 2005) or the concept of reification in computer sciences (Afshari & Su, 2016).

2.3 Assessment of Creativity

In order to collect the learning process at the team level, we use team-based diaries. Huang (Huang, 2005) cited Nunan (Nunan, 1992) and mentioned that learning diaries have been described as important introspective tools which provide researchers with great opportunities to explore learners' own perceptions of learning. The CSCL process is documented by the students through a team-based diary in which the members of the team are invited to write the organisation decisions (roles for each of the members, planning of the different tasks), the creative and productive process of building the different artefacts within the project, to reflect on their learning process and problem-solving strategies during the activities and to integrate photos and videos of their co-creative process. The learning team-based diary is used as a learning tool for students as they are collaboratively demonstrating their comprehension's evolution of educational technology's pedagogical uses. Teachers also use the team-based diary as a qualitative and formative assessment tool by which students receive feedback on their critical thinking competency for pedagogical uses of technology in the classroom. They are also asked to write about the different creation processes done in the course.

To assess each participant's creativity of their building models and pedagogical sequences, we rely on participants' learning journal, focusing on their individual reflection throughout the building process. Learning journals are both self-reflection tool and a longitudinal record of self-declared learning process and outcomes. Learners wrote a learning journal as a means of reflecting on their own thinking, which could support both cognitive and metacognitive process (McCrindle & Christensen, 1995). We also asked participants to take pictures of their building model and team-built neighbourhood from different angles to insert them in the learning diary. Both pictures and text were taken into account to assess students' creativity level in the making of the model. Regarding the assessment of the city model creativity level, teachers collaboratively assessed each building model by grading them according to a rubric-based assessment tool divided in three rating categories from a scale from 0 to 1.7: weak, good and excellent. The assessment was based on creativity criteria based on Cropley, Kaufman and Cropley (2011) and adapted to the curriculum creativity criteria of PFÉQ by Romero and Vallerand (2016): exploring new solutions, using inspirational sources to guide creative research and select a solution while considering context. The three components were separately assessed and then merge to create the grade from 0 to 1.7 points. The average grade for all 198 students was 1.5345 (sd=0.29). We choose to assess creativity with a rubric-based tool as they have shown potential in identifying the need for improvements in project-based learning and facilitate valid judgement for complex competencies when clarity and appropriateness of language in the tool is a central concern in the elaboration and sharing of the tool (Jonsson & Svingby, 2007; Reddy & Andrade, 2010). Therefore, we have previously shown and explained each grading category and their key words and gave students project examples from previous years that obtained an excellent grade so they could better understand teachers' expectancies. As the educational context required teachers to assess student production in less than two weeks, not every student work was double assessed. However, teachers were grading in team when they remotely had a doubt about the valid judgement of a production. Below are examples of students' reflection and building model. Data was analysed deductively as teachers were analysing manifestations of creativity criteria according to Cropley et al. (2011) adapted by Romero and Vallerand (2016) of the creative process. Regarding the assessment of creativity of the pedagogical sequence, teachers also used a rubric-based assessment that had five criteria including creativity decided to have a holistic assessment. They collaboratively assessed a grade on 20 points. This grade included creativity, analysis of the educational issue, overall quality of the document, in-class pilot and pedagogical plus-value of the sequence. The average grade for all 197 students was 18.268 (sd=0.74). Examples reflect the average grade as most were granted a high creativity grade. The first example, in the building model activity, shows a student displaying creative and design thinking skills in the building process as she engaged in a search to find the best adapted material for her building model. The second example, in the pedagogical sequence creation process, shows collaborative creativity as students are diverting the intended use of a Sphero robot in order to address the need of kids with dysphasia.

During the first session, our team decided that western-themed would be our urban norms. One of the difficulties that I encountered during the construction of the building model was the choice of material because the building model had to be detachable. Thus, I chose to use cork planks as well as Velcro. What was particular, though, was the material manipulation; cork being too delicate to manipulate once it is cut. It was therefore decided that exterior facing would be made with wood planks or with bricks. After doing the base of my building model, I painted it and then I used little wooden branches that I sawed.

In order to help students develop an understanding of fractions, we propose that they co-create and co-design a video game about fractions with *Learningapps.* In order for students with dysphasia to develop creativity, we agreed that they would be asked to program a *Sphero* robot that would circulate around the city model in order to help them understand the concept of angles in mathematics. The students could then film themselves explaining their creation process in order to develop their communication skills in a stress-free environment.

Figure 4. Projects with a high creativity grade

During the course, teams also had to carry out a 20-minute simulation of their pedagogical sequence in front of the other students in order for the audience to understand the main learning mechanics of their sequence. The simulations were assessed through a peer-reviewed process where each team was assessed by every student watching their simulation. This peer-reviewed process criteria, including creativity, were the same as the one teachers used to assess each pedagogical sequence. The teachers explained the criteria the students and made sure that nobody had any questions on the interpretation of selected criteria. Each student was asked to assess the creativity of pedagogical sequence in rubric-based assessment divided in three levels: “the project is not creative and not coherent with the intended learning outcomes (N1)”, “the project is somewhat original and coherent with intended learning outcomes (N2)” and “the project is creative (N3)” (see figure 5).

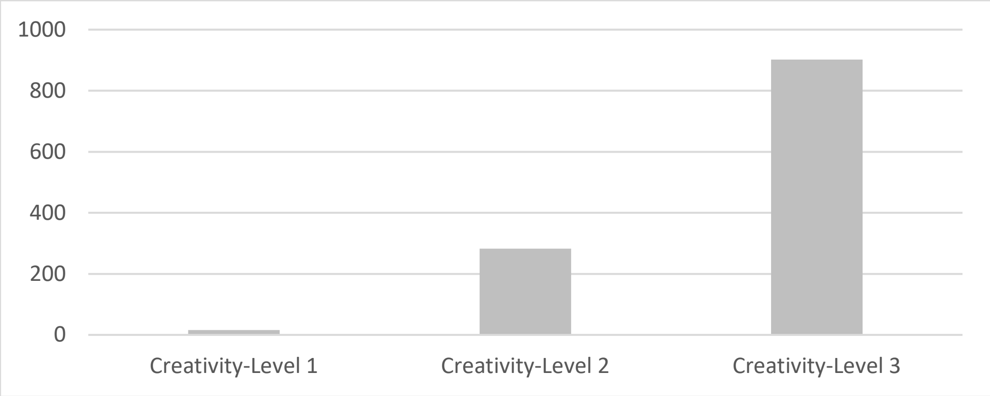

Figure 5. Peer-assessed creativity

We noticed a small difference between assessments from teachers and peers as there was more N2 project assessed by peers than N2 projects assessed by teachers. Peers were therefore slightly more severe than teachers in the assessment of creativity.

Acquisition of content-related knowledge of pedagogical uses of educational technologies was assessed through a final exam where students had to answer three questions. In the first one, students had to give five examples of creative and collaborative pedagogical use of technology. Assessment of the first question was rubric-based composed of four criteria: collaboration, creativity, identification of pedagogical plus-value of and identification of pedagogical limits. In the second question, students had to identify two 21st century competency for both teachers and students and argue why the selected competencies were important. Assessment of the second question was rubric-based composed of two criteria: the quality of the argumentation and the use of scientific sources. In the third question, students had to identify and explain two pedagogical plus-value and two pedagogical limits of using coding in class. Assessment of the third question was rubric-based, composed of four criteria: identification of pedagogical plus-value of and identification of pedagogical limits, the quality of the argumentation and the use of scientific sources. As the educational context required teachers to assess student production in less than two weeks, not every student work was double assessed. However, teachers were grading in team when they remotely had a doubt about the valid judgement of an answer. The average grade for students (n=199) was 90,7298% (SD=10,66).

Discussion

In the current Québec educational context, competency assessment is integrated in the official curriculum (PFÉQ, 2011) but is still not fully implemented into teachers' practices as it is still criticised in the public sphere as being too complex to be fully understood by teachers. Thus, it is important to provide teachers with pedagogical projects that underline 21st century competency development such as creativity (Wegerif, 2006). Projects such as #SmartCityMaker offer a possible solution to this issue as it provides fun, tangible and concrete projects while also articulating a high level of complexity where 21st-century competencies can emerge. Considering students' ability to show a high level of creativity and design thinking skills in the model building as well as in pedagogical sequence creation activity while also being able to acquire and understand content-based knowledge such as 21st-century competencies, coding, robotics and digital games, we therefore argue that a maker-based pedagogical design can support creativity without jeopardising the acquisition of knowledge. The maker-based activity has to be designed in a way that students can have a creative margin in the process and results while also feeling the need to acquire content-related knowledge in order to create their solutions. In our maker-based activity, we induced students' need to acquire knowledge about educational technologies by engaging them in an inquiry about authentic educational issues in which they had to propose a creative and original way of addressing their selected educational issue. Moreover, # Conducting #SmartCityMaker with pre-service teachers also prepares them for 21st-century teaching practices (Häkkinen et al., 2016), as it helps foster learners' collaborative creativity (Romero, Hyvönen, & Barberà, 2012) as well as collaborative problem-solving. We therefore think that #SmartCityMaker has a high transferability potential. Utilising the theme of a smart city allows for collaborative research and practices among scholars from different expertise: urban science (UMR), robotics (*Centre de Robotique et de Vision Industrielles* inc, CRVI), IT advancement (ITIS) and educational psychology. Although collaborative creativity is encouraged through #SmartCityMaker, we did not provide a framework of creativity to participants during session to help them conceptualise what our definition of creative building model was. Participants having a thorough understanding of creativity might have helped them build models with a higher creative value. Also, while participants received a written notice informing them that they would receive an assignment on the first week, they were asked to construct their building model in one week, therefore limiting participants' iterative creation process. Future research should therefore allow more time for the building assignment in order to scaffold creation process. Teachers could also explain some existing creativity framework model in class to foster participants' creativity awareness. Also, as #SmartCityMaker aims to foster collaboration through making, it would be relevant to support collaboration by implementing a sharing platform that would give students the opportunity to share the design process of the project as well as possible multiple iterations (Litts et al., 2016). #SmartCityMaker also offers a tool assessing 21st-century competencies based on a perceptible element that can simplify competency assessment by teachers. Future research should also consider how this tool could allow teachers to identify how projects can foster such competencies and encourage more professors in HE to develop creativity in their respective courses.

Acknowledgments

We acknowledge the contribution of Christopher A. Ashton who participated in the linguistic and critical revision of this paper.

References

Afshari, M., & Su, Z. (2016). Toward Rapid Transformation of Ideas into Software. *arXiv Preprint arXiv:1602.01075*.

Agency By Design. (2015). *Maker-centered learning and the development of self: Preliminary findings of the agency by design project*. Agency by Design. Retrieved from http://www.pz.harvard.edu/sites/default/files/Maker-Centered-Learning-and-the-Development-of-Self_AbD_Jan-2015.pdf

Baddeley, A. (1992). Working memory. *Science*, *255* (5044), 556.

Baddeley, A. (2012). Working memory: theories, models, and controversies. *Annual Review of Psychology*, *63*, 1–29.

Barma, S., Romero, M., & Deslandes, R. (2017). Implementing Maker Spaces to Promote Cross-Generational Sharing and Learning. In *Game-Based Learning Across the Lifespan* (pp. 65–78). Springer.

Benedek, M., Könen, T., & Neubauer, A. C. (2012). Associative abilities underlying creativity. *Psychology of Aesthetics, Creativity, and the Arts*, *6* (3), 273.

Boutonnet, V. (2015). Pratiques déclarées d'enseignants d'histoire au secondaire en lien avec leurs usages des ressources didactiques et l'exercice de la méthode historique. *McGill Journal of Education/Revue Des Sciences de L'éducation de McGill*, *50*(2–3), 225–246.

Bowler, L. (2014). Creativity through "maker" experiences and design thinking in the education of librarians. *Knowledge Quest*, *42* (5), 58.

Brahms, L. (2014). *Making as a learning process: Identifying and supporting family learning in informal settings*. University of Pittsburgh.

Brennan, K., Balch, C., & Chung, M. (2014). Creative computing. *Harvard Graduate School of Education*.

Chandler, P., & Tricot, A. (2015). Mind Your Body: the Essential Role of Body Movements in Children's Learning. *Educational Psychology Review*, *27* (3), 365–370.

Cohen, J. (2017). Maker Principles and Technologies in Teacher Education: A National Survey. *Journal of Technology and Teacher Education*, *25* (1), 5–30.

Cohen, J. D., Jones, W. M., Smith, S., & Calandra, B. (2016). Makification: Towards a Framework for Leveraging the Maker Movement in Formal Education. In *Society for Information Technology & Teacher Education International Conference* 2016, 129–135).

Cropley, D. H., Kaufman, J. C., & Cropley, A. J. (2011). Measuring creativity for innovation management. *Journal of Technology Management & Innovation*, *6* (3), 13–30.

Csikszentmihalyi, M. (1996). Flow and the psychology of discovery and invention. *New Yprk: Harper Collins*.

Davies, D. (2004). Creative teachers for creative learners-a literature review. *Undated, Internet Available: Www. Ttrb. Ac. Uk/Attachments/c30 96c7b-da04-41ef-a7ac-50535306e8fb. Pdf*.

Davydov, V. (1988). Problems of developmental teaching-the experience of theoretical and experimental psychological-research-excerpts. 1. *Soviet Education*, *30* (8), 6–97.

De Bono, E. (2015). *Serious Creativity: How to be creative under pressure and turn ideas into action*. Random House.

Desgagné, S., Bednarz, N., Lebuis, P., Poirier, L., & Couture, C. (2001). L'approche collaborative de recherche en éducation: un rapport nouveau à établir entre recherche et formation. *Revue Des Sciences de L'éducation*, *27*(1), 33–64.

Dougherty, D. (2012). The maker movement. *Innovations*, *7* (3), 11–14.

Eguchi, A. (2014). Robotics as a learning tool for educational transformation. In *Proceeding of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education Padova (Italy)*.

Engeström, Y. (2005). Toward overcoming the encapsulation of school learning. *An Introduction to Vygotsky*, 157–176.

Feder-Levy, E., Blumenfeld-Liebertal, E., & Portugali, J. (2016). The well-informed city: A decentralized, bottom-up model for a smart city service using information and self-organization. In *Smart Cities Conference (ISC2), 2016 IEEE International* (pp. 1–4). IEEE.

Florida, R. (2014). *The Rise of the Creative Class—Revisited: Revised and Expanded*. Basic books.

Franken, R. E., & Bauers, P. (2002). *Human motivation*. Wadsworth/Thomson Learning.

Garrison, D. R. (2011). *E-learning in the 21st century: A framework for research and practice*. Taylor & Francis.

Gerstein, J. (2016). Becoming a Maker Educator. *Techniques: Connecting Education & Careers*.

Glenberg, A. M., & Robertson, D. A. (1999). Indexical understanding of instructions. *Discourse Processes*, *28* (1), 1–26.

Goldin-Meadow, S., Nusbaum, H., Kelly, S. D., & Wagner, S. (2001). Explaining math: Gesturing lightens the load. *Psychological Science*, *12* (6), 516–522.

Guilford, J. P. (1962). Creativity: Its measurement and development. *A Source Book for Creative Thinking*, 151–167.

Gutwill, J. P., Hido, N., & Sindorf, L. (2015). Research to practice: Observing learning in tinkering activities. *Curator: The Museum Journal*, *58* (2), 151–168.

Häkkinen, P., Järvelä, S., Mäkitalo-Siegl, K., Ahonen, A., Näykki, P., & Valtonen, T. (2016). Preparing teacher-students for twenty-first-century learning practices (PREP 21): a framework for enhancing collaborative problem-solving and strategic learning skills. *Teachers and Teaching*, 1–17.

Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, P. (2015). A framework for teachable collaborative problem solving skills. In *Assessment and Teaching of 21st Century Skills* (pp. 37–56). Springer.

Howard-Jones, P. A. (2002). A dual-state model of creative cognition for supporting strategies that foster creativity in the classroom. *International Journal of Technology and Design Education*, *12* (3), 215–226.

Huang, J. (2005). A diary study of difficulties and constraints in EFL learning. *System*, *33* (4), 609–621.

Jahnke, I., Haertel, T., & Wildt, J. (2017). Teachers' conceptions of student creativity in higher education. *Innovations in Education and Teaching International*, *54* (1), 87–95.

Jankowska, M., & Atlay, M. (2008). Use of creative space in enhancing students' engagement. *Innovations in Education and Teaching International*, *45* (3), 271–279.

Jefferson, M., & Anderson, M. (2017). *Transforming Schools: Creativity, Critical Reflection, Communication, Collaboration*. Bloomsbury Publishing.

Johansson-Sköldberg, U., Woodilla, J., & Çetinkaya, M. (2013). Design thinking: past, present and possible futures. *Creativity and Innovation Management*, *22* (2), 121–146.

Jonsson, A., & Svingby, G. (2007). The use of scoring rubrics: Reliability, validity and educational consequences. *Educational Research Review*, *2* (2), 130–144.

Kafai, Y. B., & Resnick, M. (1996). *Constructionism in practice: Designing, thinking, and learning in a digital world*. Routledge.

Kafai, Y., Fields, D., & Searle, K. (2014). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. *Harvard Educational Review*, *84* (4), 532–556.

Katterfeldt, E. (2014). Maker Culture, Digital Tools and Exploration Support for FabLabs. *FabLab: Of Machines, Makers and Inventors*, 139–147.

Kimbell, R., Stables, K., & Sprake, J. (2002). Designers in Action: An evaluation of the impact of the Design Museum workshop series. *Journal of Design & Technology Education*, *7* (2).

Kleiman, P. (2008). Towards transformation: conceptions of creativity in higher education. *Innovations in Education and Teaching International*, *45* (3), 209–217.

Litts, B. K., Kafai, Y. B., Fields, D. A., Halverson, E. R., Peppler, K., Keune, A., … others. (2016). Connected making: Designing for youth learning in online maker communities in and out of schools.

Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *5* (1), 4.

McCrindle, A. R., & Christensen, C. A. (1995). The impact of learning journals on metacognitive and cognitive processes and learning performance. *Learning and Instruction*, *5* (2), 167–185.

Mclaren, S. V., Stables, K., & Bain, J. (2006). Creativity and Progression in Transition through assessment for learning in Design and Technology CAPITTAL-DT—a report to funders for the Determined to Succeed Division of Scottish Executive (research report to funders). attitude, meta-cognition and performance of novice designers at a time of transition. DOI: 10.13140/RG.2.2.21966.25924

Molin, L., & Grubbström, A. (2013). Are teachers and students ready for the new middle school geography syllabus in Sweden? Traditions in geography teaching, current teacher practises, and student achievement. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography*, *67* (3), 142–147.

Nunan, D. (1992). *Research methods in language learning*. Cambridge University Press.

Oliver, K. M. (2016). Professional Development Considerations for Makerspace Leaders, Part One: Addressing "What?" and "Why?" *TechTrends*, *60* (2), 160–166.

Papert, S., & Harel, I. (1991). Situating constructionism. *Constructionism*, *36* (2), 1–11.

Peppler, K., Halverson, E., & Kafai, Y. B. (2016). *Makeology: Makerspaces as Learning Environments* (Vol. 1). Routledge.

PFÉQ, Gouvernement du Québec. (2011). *Programme de formation de l'école québécoise*. Québec.

Posch, I., & Fitzpatrick, G. (2012). First steps in the FabLab: experiences engaging children. In *Proceedings of the 24th Australian Computer-Human Interaction Conference* (pp. 497–500). ACM.

Reddy, Y. M., & Andrade, H. (2010). A review of rubric use in higher education. *Assessment & Evaluation in Higher Education*, *35* (4), 435–448.

Romero, M., & Laferrière, T. (2015, December 4). Usages pédagogiques des TIC : de la consommation à la cocréation participative. *Vitrine Technologie Éducation*. Retrieved from http://www.vteducation.org/fr/articles/collaboration-avec-les-technologies/usages-pedagogiques-des-tic-de-la-consommation-a-la

Romero, M., & Vallerand, V. (2016a). *Guide d'activités technocréatives pour les enfants du 21e siècle* (Vol. 1). Québec, QC: Createspace.

Romero, M., & Vallerand, V. (2016b). *Guide d'activités technocréatives pour les enfants du 21e siècle* (Vol. 1). Québec, QC: Livres en ligne du CRIRES. Retrieved from http://lel.crires.ulaval.ca/public/guidev1._guide_dactivites_technocreatives-romero-vallerand-2016.pdf

Runco, M. A. (2014). *Creativity: Theories and themes: Research, development, and practice*. Elsevier.

Rutland, M. (2009). Art and Design and Design and Technology: Is there creativity in the designing? *Design and Technology Education: An International Journal*, *14* (1).

Shaheen, R., & others. (2010). Creativity and education. *Creative Education*, *1* (03), 166.

Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. *Harvard Educational Review*, *84* (4), 505–531.

Sternberg, R. J., & Lubart, T. I. (1995). *Defying the crowd: Cultivating creativity in a culture of conformity.* Free Press.

Tanenbaum, J. G., Williams, A. M., Desjardins, A., & Tanenbaum, K. (2013). Democratizing technology: pleasure, utility and expressiveness in DIY and maker practice. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2603–2612). ACM.

Tuckman, B. W., & Jensen, M. A. C. (1977). Stages of small-group development revisited. *Group & Organization Management*, *2* (4), 419–427.

Vossoughi, S., & Bevan, B. (2014). Making and tinkering: A review of the literature. *National Research Council Committee on Out of School Time STEM*, 1–55.

Vygotsky, L. S., & Rieber, R. W. (1997). *The collected works of LS Vygotsky: Problems of the theory and history of psychology* (Vol. 3). Springer Science & Business Media.

Wegerif, R. (2006). A dialogic understanding of the relationship between CSCL and teaching thinking skills. *International Journal of Computer-Supported Collaborative Learning*, *1* (1), 143–157.

Whyte, W. F. E. (1991). *Participatory action research.* Sage Publications, Inc.

Wiebusch, S. (2016). Archive for April, 2015. *ISSUES*, (7).

Willett, R., Robinson, M., & Marsh, J. (2012). *Play, creativity and digital cultures*. Routledge.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, *9* (4), 625–636.

Wiske, M. S., Educational Technology Center, C., MA., & And Others. (1988). *Collaborative Research Goes to School: Guided Inquiry with Computers in Classrooms. Technical Report*.