Pupils' reflections on the use of a digital self-assessment tool to identify and measure development of 21st century skills during maker activities in schools

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ABSTRACT

The number of makerspaces is increasing in the world, and the maker movement has started to become integrated into formal education. Maker environments and maker activities are argued as promoting Key Components for Lifelong Learning, e.g. collaboration, problem solving, creativity, life/social skills and communication. These competences are also referred to as 21st century skills. In this paper, we discuss the use of a digital self-assessment tool (DSAT) for pupils' identification of, and reflections on, their development of these skills. The DSAT was created with gamification as the model where the pupils could reach different levels, receive badges and upload photographs. There were 65 pupils aged 13-15 years, participating in the study, working with different maker activities in technology subject classes, while using the DSAT. Examples of maker activities used in this study included designing a liquid-bottle, programming with Micro:bit and programming with Roblox. Data were collected through group interviews after the activities with all participating pupils and thereafter analysed thematically. The pupils found the language in the DSAT difficult considering their age and thought that the tool was time consuming and troublesome to use. However, the pupils argued that it is possible to develop 21st century skills during maker activities in school contexts and that the skills are of importance for the future. This study contributes with important knowledge about the design of digital self-assessment tools and about design of technology education, to support pupils to identify and develop 21st century skills in makerspace activities in compulsory technology education.

Key Words: Maker activities, self-assessment, 21st century skills

1. INTRODUCTION

Makerspaces have started to be an integrated part of school settings (e.g. Vourikari, Ferrari & Punie, 2019). It is argued that makerspace activities can be seen as conducive environments for learning 21st century skills (e.g. Sheffield et al., 2017; Sheridan et al., 2014) e.g. digital competence; competence in science, technology, engineering, and mathematics (STEM); entrepreneurship; analytical thinking; problem-solving; creativity, etcetera (Vourikari et al., 2019). The European Commission (2019) lists skills that are important for education and for future work: creativity, problem-solving, critical thinking, and digital literacy, often referred to as 21st century skills (e.g. Bell, 2010; Davies et al., 2011; Jang, 2016). However, it can be challenging to assess the development of these skills, and there is a lack of tools connected to assessment of, for instance, creativity (e.g. Sawyer, 2003). In this paper, we present a pilot study where the focus is on how a recently developed digital self-assessment tool (DSAT) can be used to identify development of 21st century skills when pupils are engaged in makerspace activities. Focus is on self-assessment of the skills *collaboration*, *creativity*, *problem-solving*, *life/social skills* and on *communication*. We are also interested in how the tool is experienced by the pupils from a design perspective and if the tool supports the development of understanding 21st century skills.

2. AIM AND RESEARCH QUESTIONS

The aim of this pilot study is to investigate if and how a digital self-assessment tool can stimulate understanding and development of 21st century skills in makerspace activities and how the design of the tool can be supportive in this aspect. The following research questions are posed:

- How do pupils respond to the design of the digital self-assessment tool?
- How do pupils respond to the use of a digital self-assessment tool in terms of understanding and identifying development of 21st century skills during makerspace activities in formal educational settings?

3. BACKGROUND

Makerspace activities were first aroused in voluntary non-formal learning environments (e.g. Sheridan et al., 2014) and are characterised as being open-ended, collaborative, and experimental (Godhe et al., 2019; Nemorin & Selwyn, 2017; Sheridan et al., 2014). Several challenges need to be considered when makerspace activities are implemented in formal school settings based on curricular goals, assessment, and organisational priorities (e.g. Godhe et al., 2019; Walan & Gericke, 2023). Teachers need to relate the activities to learning outcomes and curricular goals. However, there is an interest in integrating makerspace activities into schools (e.g. Oliver, 2016), and one reason for this is to fill the gap of educating for the development of 21st century skills (Samuelsson Wardrip & Brahms, 2016).

Previous studies report that pupils develop 21st century skills and learn about technological information and design when working with makerspace related activities, such as 3D printing (e.g. Coşkun & Deniz, 2021; Novak & Wisdom, 2019). The skills used in the DSAT will be described briefly.

Collaboration can be described as an active form of learning with at least two (a group of) individuals, working together to solve a problem, complete a task, or create a product in a physical or virtual environment (Kirschner et al., 2018; Laal & Laal, 2012; Marinez-Moyano, 2006).

Creativity can be understood as a process over time, where novel products are produced (Sawyer, 2003). However, the novelty can arise from new combinations of previously known elements. Creativity can be seen as a method for problem-solving (Amabile, 1996); thus, in order to develop learners' creativity, stimulating environments and materials are needed (Gauntlett et al., 2010).

Problem-solving can be defined as a process where mental representations of a solution to a problem are created (Jonassen & Hung, 2012). If a problem is ill-structured, i.e. where the information required to solve the problem is incomplete, the pupils need to follow different paths and consider various ideas, and at the same time developing creativity and critical thinking (Lai & Viering, 2012).

Life/social skills can be understood as a combination of different skills that are important for navigating through personal and working life. For instance, to be able to take initiatives; have self-direction; to be flexible, adaptable, and productive; act responsibly and finally, have the ability to inspire others.

Communication can include several different aspects, for instance, the interrelation between reading, writing, speaking, and listening (Thompson, 2020). People with good communication skills can express opinions, discuss, reason, speculate, argue, and debate (Lai & Vering, 2012). They can also listen and communicate in different situations, and they are also good at using multimedia when communicating. In addition, they can inspire and create enthusiasm among others (Lai & Vering, 2012).

Makerspace activities can be a challenge in school settings, since the outcomes can differ a great deal (Lin et al., 2020). However, assessment often concerns three different areas: a) content understandings, b) feelings and attitudes, and c) commitment and collaboration (Lin et al., 2020). The content often refers to programming skills, programming concepts, computer logical thinking, creativity, and problem-solving abilities. In these areas, research literature states that formative assessment can support pupils' understandings and help them increase commitment and learning (Hadad et al., 2020; Maltese et al., 2018). In addition, makerspace activities have a potential to create learning opportunities from failure and the formative assessment can stimulate development of pupils' knowledge (Hadad et al., 2020).

4. MAKERSPACE ACTIVITIES AND SWEDISH TECHNOLOGY EDUCATION

In Sweden, the syllabus on technology education is divided into three parts with different core contents, respectively; grades 1–3, grades 4–6, and grades 7–9. However, the aim of the technology subject and the skills the pupils should develop are the same throughout grades 1–9. Teaching should provide pupils with opportunities to develop; the ability to reflect on different choices of technical solutions; their consequences for the individual, society, and the environment; and how technology has changed over time; knowledge of technical solutions and how constituent parts interact to achieve suitability and function; and the ability to carry out technology development and design work. The teachers have a great deal of freedom in organising the learning environments to meet the aim of the subject. In addition, pupils should be prepared in Swedish compulsory schools for an active, creative, and responsible participation in society with a lifelong desire to learn (Swedish National Agency for Education, 2018). Pupils should also be given opportunities to solve problems, turn ideas into action, and to work both individually and in collaboration with others, with and without digital tools for creation and communication. We focus in this study on the core contents for grades 7–9 (pupils aged 13–15), and we interpret the following contents, which are also connected to makerspace activities.

- How do mechanical and digital technology interact?
- Technical solutions that use electronics and how they can be programmed.
- The different phases of technology development work: identification of needs, research, proposals for solutions, design, and testing. How do the phases of the work process interact?
- Own constructions where control and regulation are applied, among other things, with the help of programming.
- How digital tools can be a support in technology development work, for example, to make drawings and simulations?
- Documentation in the form of manual and digital sketches and drawings with explanatory words and concepts, symbols and dimensions, as well as documentation with physical and digital models.

It is important to note that there are no learning outcomes explicitly addressing 21st century skills in the syllabus for the subject technology. In this study, the teachers, together with the pupils, test the use of DSAT in makerspace activities in formal learning contexts, and where the focus is shifted from assessment to self-assessment. Self-assessment is a broad concept, covering feedback from oneself, with the purpose of generating information that promotes learning and performance (Andrade, 2019). The feedback should be formative in nature; otherwise, it is pointless, argues Andrade (2019). We also find in the Swedish National Curriculum for Compulsory School (Swedish National Agency for Education, 2018) that pupils should develop their ability to assess their own results, hence self-assessment.

5. THE TOOL

The DSAT was developed by partners in a European project in an iterative design process. The relevance of the DSAT to maker activities is explained in detail by Ioannou et al. (2020). In this project, our role was to test the DSAT in classes. The DSAT is supposed to be used by pupils aged 12–18 years, with the aim of making them reflect on their development of 21st century skills in makerspace activities. The tool is designed as a game with different levels to reach, and badges to collect. Within the tool, pupils respond to different challenges and answer questions. There are also possibilities to upload photos of activities where the pupils themselves think they are creative, collaborative, communicative, etcetera.

The DSAT includes written definitions of each of the 21st century skills, so pupils can check the definitions if they feel uncertain about the meanings. Graphically, the tool is designed to appeal to the target group. It is possible to use different devices, such as PCs, tablets, or smartphones, since the tool is based on an online platform.

6. METHODOLOGY

To meet the aim of this study and to answer the research questions, 14 qualitative group interviews were conducted with 65 pupils from lower secondary school (pupils aged 13–15 years). The pupils and their parents provided consent to participate. The participants came from two different lower secondary schools, from six different classes, ranging from grade 7 to 9. The six classes worked with different makerspace activities, planned by the respective teachers in discussion with the first author, in accordance with the European project. Both authors visited the classes and informed the pupils about the project, and each teacher informed the pupils about the DSAT and helped them with guidance when they started to use the tool. Examples of makerspace activities they used include: programming in Scratch and Micro:bit, designing different kinds of packages, and design of an online application for smart phones. These activities were held at the respective school. A final activity was held in localities at the university, in collaboration with the local makerspace. In this final activity, programming within Roblox was performed. The activities lasted between 2 to 6 weeks, with one or two sessions per week. After each session, the pupils used the DSAT, aiming to self-assess what kinds of skills they had been able to develop.

After the final activity, group interviews were held at the university. The groups comprised 5–6 pupils. The interviews were thematically analysed (Braun & Clark, 2006). The second author did the first tentative analysis; thereafter, both authors discussed and compared the themes until a consensus was reached.

7. RESULTS

The analysis resulted in two main themes: *The use of the DSAT* and *The 21st century skills* with sub-themes, respectively (Table 1). The results will be presented next with excerpts from the interviews, named G1 for group 1, G2 for group 2, and so forth (in total 14 groups).

Table 1.
Themes and sub-themes

Theme	Sub-theme
The use of the DSAT	Purpose of using the tool Functional issues with the tool Suggestions for improvements of the tool
The 21st century skills	Understanding Development of 21st century skills

7.1. The use of the DSAT

The first theme includes three sub-themes (see Table 1). The pupils found the *Purpose of using the tool* to be: to evaluate and reflect upon their work or the results of their work. 'I think in retrospect, to be able to check later what we have done, to learn from it, maybe' (G3). There were also statements from pupils not grasping the purpose of the tool. 'I don't understand why you should use it' (G3).

During the interviews, pupils described some *Functional issues with the tool*. Specifically, they stated that the language in the tool was too difficult, there were too many similar questions and loops, and it was time consuming with the need to do many clicks. The pupils did not perceive the tool to be intuitive. In addition, the pupils expressed it was difficult to upload pictures. 'It was complicated words… if you don't read 24/7… it was difficult to understand' (G12).

The pupils described some *Suggestions for improvements of the tool*, albeit this was not asked for during the interviews. They said it would be helpful if the tool had video-instructions for how to navigate and use the tool. 'They could have made a video before, so it was possible to see how to use the tool' (G11). Another suggestion was that the tool could include some exercises for training skills that were not so developed. Finally, the pupils suggested that the questions could be more open-ended to stimulate their reflections about the skills.

7.2. The 21st century skills

The second theme includes two sub-themes (see Table 1). The pupils expressed that the DSAT helped them in their *Understandings* of some of the 21st century skills. 'It makes you reflect. For instance, about how you collaborate with others… so you can improve… if you notice that you never collaborate, you can start doing that' (G14). However, pupils had some difficulties understanding the life/social skills, and other skills seemed to overlap in definitions when the pupils talked about them. One pupil said 'You collaborate automatically and improve communication automatically when you collaborate' (G9).

It was also found that pupils thought about problem-solving in different ways, often linked to everyday perspectives and learning, such as how to open a door. 'Well, a problem can be that when you are a small kid, you cannot open doors, but when you become older, you solve the problem and understand how to do it' (G10).

Further, the pupils believed that it is possible to *Develop 21st century skills* while doing makerspace activities. Above all, the pupils mentioned the skill of creativity and that open-ended activities promote creativity. However, they also said that it is possible to develop these skills by doing other activities as well and that the skills are important for them in the future.

8. DISCUSSION AND CONCLUSIONS

From the results, we can conclude that not all pupils have understood the purpose of using the DSAT. One explanation for this is that the tool may not be intuitive enough for the pupils to understand or that they did not understand their teachers when the tool was being introduced. We are also uncertain about if and how often the pupils have been doing self-assessment activities, which can impact the understandings.

We draw the conclusion that designing a self-assessment tool is a difficult task. Furthermore, the interviewed pupils gave a lot of examples of this, such as requiring a lot of clicks, and too many similar questions in the different parts of the DSAT. Moreover, uploading pictures was considered problematic, both technically and to capture a skill in a photo. The pupils did not know what to focus on in the picture. The language in the DSAT may be too complicated, and the translation from English to Swedish can be improved.

We argue that the role of the teacher is important for helping pupils understand the skills and how to use the tool; having only written definitions in the tool is not enough according to our results. Some pupils suggested videos as complements for support and information.

One finding from this study is that pupils became aware of the 21st century skill when using the DSAT and when participating in makerspace activities, a result also found in other studies (e.g. Sheffield et al., 2017; Sheridan et al., 2014; Vuorikari et al., 2019). During the interviews, these skills were described as being important for the future.

The results also show that some of the 21st century skills are understood as overlapping, for instance, collaboration and communication. Furthermore, the pupils found it difficult to fully understand what was meant by life/social skills. We think that one explanation for this can be that the Swedish language has no word for life/social skill.

The pupils suggested that the DSAT could be developed to include activities or tasks that help to improve 21st century skills. We believe this is an important aspect when working with self-assessment. As Andrade (2019) argues, pupils should be given opportunities to work with corrections and adjustments. However, this is not possible in the current DSAT.

Finally, if self-assessment tools are to be used by pupils who are not used to performing self-assessments, they need to have the opportunity to practise. Exploring additional viewpoints from pupils, including aspects like setting goals, making plans, self-confidence, inherent curiosity, personal values, emotional reactions, and similar factors, was not within the scope of this current research. Nevertheless, incorporating these elements could offer a more comprehensive

understanding of how pupils might react to the design and utilization of the DSAT or other analogous tools created for comparable intentions.

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