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The Influence of Teachers' Perception of Creativity and Makerspaces on Their Practice in Norwegian Compulsory Schools

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Abstract
The use of makerspaces in Norwegian compulsory education is growing. However, using maker-centred learning to support creativity has yet to be examined extensively in the Norwegian context. Consequently, the aim of this research is to explore Norwegian makerspace teachers' conceptions of the use of maker-centred learning to augment creative capabilities and digital competences. The study focuses on teachers' understandings of creativity and makerspaces along with various aspects of maker-centred learning and how they support creativity. The data was collected via six semi-structured interviews with teachers working in school-based makerspaces. In the interviews, the teachers conceptualised creativity related to makerspaces and reflected on various pedagogical aspects of managing creative makerspace activities. The research indicates that teachers have similar understandings of makerspaces but different interpretations of creativity. As a result, the makerspaces are designed differently, and the teachers use a variety of teaching methods. The findings also indicate that the teacher must be able to change their role from being an instructor to a facilitator and observer while also managing the utilised technology. Digital technology, collaboration, and constraints were also found to be factors that supported students' creativity.

Keywords
Creativity, Norwegian compulsory education, makerspaces, maker-centred learning, invention pedagogy

Introduction
In recent years, several Norwegian schools have established makerspaces. In the context of education, makerspaces are physical spaces within schools that feature activities based on creativity and where students are given opportunities to craft innovative artefacts using both manual tools and digital technology (Clapp et al. 2016). Such makerspaces have emerged as the educational potential of the maker movement has been acknowledged (Blikstein, 2013). According to Halverson and Sheridan, the maker movement refers to "the growing number of people who are engaged in the creative production of artefacts in their daily lives and who find physical and digital forums to share their processes and products with others" (Halverson & Sheridan, 2014, p. 496). Makerspaces at schools are also referred to in the literature as technological and design-based education.

Much of earlier maker research has focused on STEAM (science, technology, engineering, art, and mathematics) learning in makerspaces at museums and public libraries as well as in non-formal learning environments such as after-school programs, summer camps, or community centres (Brahms & Werner, 2013; Halverson et. al., 2017; Sheridan et al., 2014). The recent growth of school-based makerspaces has also fuelled research interest to analyse the potential of makerspaces and maker education in compulsory education (Kajamaa & Kumpulainen, 2019; 2020; Riikonen et al., 2020; Wohlwend et al., 2017). Many of the aspects that are highly valued in makerspaces – such as hands-on activities, maker mindset, and a community of practice – are also regarded as important factors in formal education. Furthermore, there is strong belief that makerspaces and maker activities can transform education by fostering 21st-century skills, democratising digital fabrication tools, and combining interdisciplinary connections to STEM (Blikstein, 2013; Martin, 2015; Riikonen et al., 2020). The term *21st-century skills* refer to knowledge and personal qualities that are necessary to succeed in unpredictable times. Unpredictability follows rapid change, necessitating, among other things, flexibility, creativity, problem-solving, collaboration and critical thinking (Piirto, 2011).

Some educators consider 21st-century skills ill-defined and heavily utilized by institutions and policymakers to promote their educational programs to legislators and businesses, hoping to participate in the global economy. Moreover, there is need to integrate the ideas of Education for Sustainable Development (ESD) and Global Citizenship Education (GCED), which could shed light on the wider context of adopting values, attitudes and skills that would benefit humanity not only in the twenty-first century but also in the future (Cleminson, 2021). However, tensions are evident between school-based makerspaces that emphasise standards-based curriculum and informal out-of-school makerspaces that prioritise open-ended material exploration and individual-initiated projects. Furthermore, contradictions exist about the teacher's role as an instructor or facilitator (Godhe, et al., 2019).

One of the central aims of including makerspaces in formal education has been to support students' creativity and innovativeness through interdisciplinary and collaborative learning and, thus, to help fulfil the intentions of the national curriculum. The current Norwegian national curriculum for compulsory education was implemented in 2020. The core curriculum, which describes the values and principles for primary and secondary education, stresses the importance of supporting creativity and innovation (Kunnskapsdepartementet, 2017). Nevertheless, these values are not always visible in the learning goal descriptions for each school subject (Dale et al., 2011). Consequently, it can be unclear how teachers are expected to support the development of creative skills in students and foster an innovative learning environment. A growing number of schools in Norway have established technology-rich educational makerspaces equipped with digital fabrication tools and materials for creative production. Nevertheless, makerspaces at schools are not a new phenomenon in many Scandinavian schools. In Nordic countries, craft, design, and technology education have been considered part of compulsory education for a century (Olafsson & Thorsteinsson, 2011). In the Nordic countries, these subjects have been taught in specific classrooms designed to foster similar activities but with a clear focus on learning skills and making quality artefacts (Seitamaa-Hakkarainen & Hakkarainen, 2017). Educational makerspaces add to this setting due to their cross-curricular activities and STEAM focus.

Teachers' understanding of creativity affects how they support student creativity (Bereczki & Kárpáti, 2018; Olafsson, 2022). Generally, teachers have a positive attitude towards creativity and want to support their students' creative development (Olafsson, 2022). However, the teacher's perception of creativity can affect the development of students' creativity skills

(Davies et al., 2013). Therefore, it is important to understand how teachers perceive creativity and makerspaces and how their perception influences their practice.

This article discusses aspects of creativity and makerspaces by first examining literature related to creativity in the context of educational makerspaces. Then, the research setting, and data collection are presented, and the results of the data analysis are reported. Finally, the authors discuss the findings and draw conclusions.

The research reported in this article is part of a research project that focuses on maker education in Norway (www.usn.no/maker). The aim of this project is to investigate how makerspaces are used and what type of pedagogical practices and values are present. Furthermore, it seeks to offer opportunities for researcher–teacher partnerships to examine how teachers can best facilitate and scaffold students' innovation processes by implementing new pedagogical practices in schools.

Creativity in maker-centered learning

Makerspaces are creative and uniquely adaptable learning environments equipped with tools and materials that provide structures for inclusive, creative, and innovative collaboration among pupils to allow for multi-disciplinary problem solving and open the doors to the world of technology (Hakkarainen & Seitamaa-Hakkarainen, 2023; Loertscher et al., 2013). Makerspaces can facilitate participation in real-life projects that helps students develop important problem-solving skills, critical thinking, and teamwork. The tools applied by students in makerspaces are often hybrid in nature, utilising both digital manufacturing technology (Hawken et al., 2013) as well as traditional technology such as hand tools and tangible craft materials.

Maker-centred learning is based on active student- and project- or problem-based learning, thus boosting students' agency and their awareness of how they can modify the world around them through engaging in creative activities. The pedagogical background of maker-centred learning leans on the work of constructionism theorists (Blikstein, 2013). The pedagogical frame often met in makerspaces develops the constructionist mentality through collaborative, flexible, student-driven, and multi-disciplinary practices and provides the space and time necessary to cultivate miscellaneous knowledge, skills, and ways of thinking. Computer-aided design and manufacturing have given rise to maker-centred learning in which the aim is to foster creativity supported by digital technologies and artefact-focused making (Clapp et al., 2016). Studies have also indicated that the makerspace culture motivates students to innovate, which augments their self-perception and creativity. Positive self-perception substantiates a student's feeling of belonging to a makerspace community (Carbonell et al., 2019).

Maker-centred learning through collaboration facilitates ways of obtaining understanding that differ qualitatively from more traditional classroom situations (Korhonen et al. 2022). When students share knowledge and reflect in collaborative settings, they gain a deeper understanding of their undertakings and how they can participate in developing the world around them (e.g. Sawyer, 2019). Maker-centred learning is concerned not only with making but also with fostering the maker's capacities to observe closely, explore complexity, find opportunities, and influence future conditions (Clapp et al., 2016). This type of learning also provides opportunities to create personalised projects and products that are meant to connect to students' own lived experiences and that demonstrate authenticity.

Research has demonstrated that learning in makerspaces enhances the design-thinking, problem-solving, and cognitive skills of students and supports creativity (Timotheou & Ioannou, 2021; Taheri et al., 2020; Hatzigianni et al., 2021). Moreover, it also supports group creativity via co-creation in maker-based work (Lille & Romero, 2017). Interactive and well-planned pedagogy is critical for enhancing creativity in makerspace settings (Giannakos et al., 2017; Bower et al., 2020; Trahan et al., 2019). According to Clapp et al. (2016), the main role of teachers in maker-centred classrooms is to act as facilitators. Moreover, their roles vary from offering direct instruction and advice to modelling behaviours and mentoring (Smarason et al., 2021). Students must be the driving force in the creative process in a maker-centred educational setting to support innovation. Odey et al. (2015) stated that teachers should focus on students by assigning tasks that inspire teamwork and risk-taking. The conventional teacher-centred role can be altered using different models (Heinze, 2008; Bonk & Cunningham, 1998), and the emphasis can be placed on open communication and similar roles between students and teachers in makerspaces (Jonsdottir & Macdonald, 2011)

Creativity

The word *creativity* is used in different contexts and different meanings are ascribed to it. However, there has been a broad consensus among creativity researchers that creativity is something new and task appropriate (Helfand, et al., 2017; Runco & Jaeger, 2012). Nevertheless, the criteria for what counts as creative are also defined by the context of the creative act. As an example, what accounts as creative for a young student in an educational setting is not necessarily a creative contribution to a professional domain.

This standard definition of creativity refers to a creative product. However, creativity is manifested in a process as well (Green et al., 2023). Traditionally, instruction in the arts in compulsory education in Norway has been focused on producing artefacts (Randers-Pehrson, 2016). In contrast, teaching and learning in makerspaces focus on the creative processes of problem solving that lead to new innovations and design (Korhonen, 2022), often in the form of prototypes. The process of conceptualising ideas in the mind, also known as idea generation, is essential to most problem-solving situations. Since idea generation is the foundation of both invention and design, it is justifiably acknowledged to be an important stage in the invention process (Van de Ven et al., 2000).

Creativity is a central element of learning (Beghetto & Kaufman, 2007; Sawyer, 2012) and internalising new knowledge. Instructionism involves knowledge that is transferred by the teacher to the student, who is then expected to memorise the content. According to Sawyer, this approach results in shallow knowledge, and Sawyer further adds that it is not possible to be creative with shallow knowledge. By contrast, creative knowledge is gained through creative activities. When the student learns though creative knowledge, they understand what they learn (Sawyer, 2012).

Amabile (2013) described four dominant components that must be present for creativity to occur: domain-relevant skills, creativity-relevant skills, task motivations, and a supportive social environment. *Domain-relevant skills* concern the professional knowledge and experience that are applicable to being creative in a field. To be creative in a specific field of knowledge, one requires in-depth knowledge of that field. However, the ability to work with multiple solutions to a problem also requires some competence in other fields. *Creativity-relevant skills* concern general skills and personal qualities such as endurance, the ability to think differently, flexibility, and openness to new ideas. *Task motivation* applies to the individual's attitudinal approach, such as commitment and passion, and high internal task motivation results in more creativity. The *social environment* concerns the working environment and surroundings, which can be supportive or obstructive to developing creative ideas (Amabile, 2013). In the context of education, the school's leaders, school traditions, and teacher–student communication can affect students' motivation and creative outcomes. Furthermore, none of the above elements can be separated from the social and cultural context of the individual. Consequently, the context of the maker activities influences the development of students' creativity.

Robinson and Aronica (2015) stated that many scholars believe that creativity can transform and reimagine education. Makerspaces, in the context of innovation, aim to provide a setting that stimulates students to think creatively, experiment with novel concepts, and push the limits of innovation. A makerspace enables students to construct prototypes and experiment, thereby transforming ideas into workable solutions through access to tools and resources. Makerspaces also offer settings in which students may improve their creations, learn from their failures, and enhance their comprehension of a variety of subjects (Smarason et al., 2021).

Among other skills, creativity has been depicted as a vital 21st-century skill (Piirto, 2011) along with competency in digital technology (Van Lar et al., 2017). Although 21st-century expertise is much broader than digital skills, it can be argued that digital mastery is essential to be creative in many domains. These skills converge in makerspaces. Digital technology can boost creativity in education by providing new resources, platforms, and settings for creative learning. This is not to say that all digital technology will facilitate student creativity, but digital components can scaffold creative learning (Glăveanu et al., 2019).

In addition, numerous studies have demonstrated that task limitations – including product configurations, design specifications, a narrowly defined issue scope, or external objectives – may stimulate creativity (Rietzschel et al., 2014; Medeiros et al., 2014). Moreover, creative thinking may be stimulated by a variety of resource constraints, such as those pertaining to time, money, knowledge, or resources.

Educators in the European Union believe that technology may foster creativity and learning and that it can be applied in any school subjects (Cachia & Ferrari, 2010). Teachers have a positive attitude towards creativity and are the key to stimulating students' creativity in makerspaces. However, teachers' perceptions of creativity are dissimilar, which influences their teaching practices and evaluations (Olafsson, 2020). Although teachers exhibit a positive attitude towards creativity, they can find it challenging to convert their ideas into effective practices (Bereczki and Kárpáti, 2018). Teachers require an appropriate understanding of the role that creativity plays in knowledge creation and must learn how to meet related challenges in the classroom (Olafson, 2022).

Method

The aim of this research was based on case study methodology to examine how teachers' conceptions of creativity and makerspaces affect their work in Norwegian compulsory education. The case was carried out in a Norwegian makerspace and the methodology used to respond to real-life situations and changing perceptions. Data was collected via qualitative interviewing that is a key method in the human and social sciences. It was based on illuminative paradigm from the interviews including transcription, coding and determining core themes (Cohen et al., 2007). The analysis was based on Miles et al. (2014) method. The research questions are as following:

1. How do teachers define creativity and makerspaces in Norwegian compulsory education?
2. How does teachers' understanding of creativity and makerspaces affect their work?

Six interviews were conducted in 2022 with nine in-service schoolteachers working with makerspaces at their schools. An internet-based communication platform was used for the interviews due to the geographical spread of the schools. The interviews were conducted by the first author and other collaborators in the maker research project. The schools were selected because they already contained established school-based makerspaces, and the teachers were instructing upper secondary level students, ages 14–16. Five interviews were conducted with solo participants, and the remaining interview had four participants. The interviews were open-ended and were based on a semi-structured framework that allowed for follow-up questions, which enabled the researcher to delve more deeply into issues of interest that emerged during the interviews (Cohen et al., 2007). The themes of the semi-structured interview guide were (a) the use of the makerspace, (b) creativity, (c) planning and executing classroom activities, and (d) assessment. Each interview was 40–60 minutes long. The interviews were transcribed verbatim, analysed, and coded in the NVivo computer program, and the transcripts were read multiple times to identify structures and themes within them. The analysis was based on Miles and Huberman's (2014) method for analysing qualitative data. The coding process consisted of two phases and used analytical memos to help define the structures (Miles et al., 2014). In the first phase, both deductive and inductive approaches were used for coding. Twelve codes were pre-defined, and six codes emerged during further analysis, eighteen in total. The predefined codes came from the literature and were connected to themes and questions in the semi-structured interview guide. Ten of these codes were used to describe the data in three categories, that were in line with the themes from the interview guide. Table 1. shows the categories and codes. The ten codes were selected because they were best suited to answer the research questions.

Table 1. Categories and codes

Categories	Codes
Definitions of creativity and makerspaces	– Creativity definition – Makerspace definition
The use of makerspaces to foster creativity	– Creative processes – Motivation – Constraints in student projects – Open-ended projects
The teacher's approach in makerspaces	– Teachers' role – Student project design – Classroom atmosphere – Teacher feedback

Findings

In this section, the results are presented in the three categories that emerged from the data:

- Definitions of creativity and makerspaces,
- The use of makerspaces to foster creativity, and
- The teacher's approach in makerspaces.

Definitions of creativity and makerspaces

The teachers were asked during the interviews to define the terms *creativity* and *makerspace*, and their responses defined creativity with various terms, such as thinking outside the box, having many ideas, trying new things, and finding solutions. Descriptions such as creative and innovative were used interchangeably. One of the teachers described creativity as making choices: "*Creativity is making choices and giving grounds for why. … It is making choices based on knowledge of materials. ... That is a big part of creativity*"*.*

Three teachers emphasised that creativity builds on other ideas and that the students' task is to find a new approach and combine different possibilities. Facilitating the possibility to combine knowledge from various school subjects was considered important for students' creative expressions: *"[What they make] doesn't have to be completely new, but it must be their own. They must make something themselves; something that is new to them or new to us. To be creative is for them to combine different things into something of their own".*

The teachers were asked whether creativity was innate. All of them stated that it was innate to a certain point, but they emphasised that creativity could be developed in the context of education:

> *I think it's a bit of both. With some, it's just like they only have visual means in their DNA. They understand what balance is, what contrast is, "this is something I can do"; it's aesthetically pleasing when they make things. While others must have more explanations as to "why should I place things in the golden ratio", "why should I put a poster together the way it should", "how should I manage to get the attention of the viewer?" They must have a more knowledge-based explanation. But I definitely think you can learn it [creativity]. I know you can learn it, … but some people just have it. They are lucky.*

Some teachers described creativity as involving personal traits such as daring to act and being independent. Furthermore, resilience was described as important: *"[The students] may come up with bad ideas, but that is part of creativity… they should try and see how it goes".*

Most of the teachers stated that technological tools of the makerspace were important for students' creativity:

> *[A makerspace is] a place where students can come and work exploratorily and use their creativity. You have tools that make it easier to work with problem solving and the new learning goals … that the new teaching plan demands. [A makerspace] is a place to work on collaboration, exploration, and creativity in a different way.*

Two teachers stated that, at the beginning, they used non-creative projects to teach their students how to use the various machines. This, then, allowed later use of machines to enable creativity when the students began to work on more open creative projects in the makerspace. Consequently, one teacher highlighted that creativity was emphasised more with older students.

When defining a *makerspace*, all of the teachers except one explicitly referred to it as a place in which students utilise their creativity by making things. One teacher emphasised the importance of making without mentioning creativity: *"[Makerspace] is a room with technical equipment where [students] can make things … first on the computer and then on a 3D printer, for instance".* Other concepts were mentioned, such as a makerspace being a place for exploring, building, and collaboration. All of the teachers considered makerspaces to be connected with technology, such as 3D printers, smart cutters, Legos, and laser cutters. However, one of the teachers remarked that makerspaces did not necessarily have to involve technology:

> *[A makerspace] doesn't have to have anything to do with technology. Sometimes, it has something to do with technology because we are working with programming. But if you could use arts and crafts to express yourself, then I think you could have the same thing there. It's about expressing opinions or knowledge through a product, after all; it applies to both arts and crafts and the creative makerspace.*

The most important aspect, therefore, is to create an environment in which creativity and innovation could occur. A makerspace was further described as a place in which students can experience mastery in ways that differ from the traditional classroom: *"[In the makerspace], there is perhaps a slightly lower threshold for getting started with the creation process. You have digital aids so that you can implement your creativity in different ways. … It is a good place to explore and be curious".*

The use of makerspaces to foster creativity

The teachers used different approaches to teaching and supporting creativity in the makerspaces. Some worked with ready-made kits, such as Lego robot and micro-bit kits, while others emphasised open-ended creative processes. The teachers considered the use of ready-made kits to be both creative and contingent on problem solving. According to one teacher, some students were not accustomed to building things by themselves without the use of pre-defined projects; therefore, they found doing so challenging. However, according to other teachers, one of the goals of the makerspace activities was to teach students to work with open-ended creative processes. For instance, one teacher interpreted this to mean teaching students to be open to new ideas, take risks, persevere, be independent, be comfortable with making mistakes, and tolerate uncertainty in the creative process. Another teacher said, "*The most important reason for me [to utilise makerspaces] is that the students get a chance to explore within a context that they know, to some extent, from before and are not afraid to work with*".

Some of the teachers said they often began by teaching the students a variety of techniques before unleashing them to work creatively. However, most teachers were aware of not spending too much time on teaching and technologies, such as programming, before students could begin working with their own creative three-dimensional products. One of the teachers chose not to provide students with information at the outset; rather, the instruction took place during the process of students working on their projects. He stated that it was preferable to provide information after the students had begun, because then they could connect the new knowledge directly to their products and processes.

A few respondents mentioned that the relevance of the projects was important to enhance student creativity. The digital tools used in makerspaces were considered to be pertinent for students' learning and their future working lives. In addition to relevance, the teachers also mentioned increased motivation. Sometimes students who were not motivated to work in other classes exhibited greater enthusiasm when working in a makerspace. One teacher stated the following:

> *I planned to work on the weather station project for three to four weeks last year… but I extended the period to eight weeks. I made that choice because the students were highly motivated to make a good product. I had one student who had problems with theory, i.e., reading, writing, math, and natural science. But after his first day in the makerspace, he still thought it was difficult, but now he is smiling in these classes. … Finally, he could show what he was capable of.*

That same teacher also reported that the student's motivation to engage in theoretical subjects had increased after their working session in the makerspace. Other teachers reported that some students were inspired to work in the makerspaces, while others were not. However, most of the teachers stated that students did exhibit greater motivation overall in the makerspace compared to most other curriculum-related activities. However, one teacher who also taught arts and crafts stated that the students did not exhibit higher motivation levels in makerspaces than they did in arts and crafts classrooms.

According to two teachers, constraints are also important for students' creativity. Without constraints, the students felt it was difficult to begin a project or produce ideas. As one teacher observed, "*The criteria are the same for all students, but what they end up with is largely different. For me, that is the difference between the makerspace and other subjects*". Another teacher who emphasised open creative processes reported that students worked only at a model level, and the model became the final product.

The teacher's approach in makerspaces

The research identified the significance of the makerspace teacher occupying multiple roles to support students' creativity. The teachers identified their role in planning the activities, preparing the classroom, and taking care of the technology. Furthermore, for creativity to thrive, all of the teachers said they were aware of their role as facilitators and observers. The teachers also underlined the importance of being able to shift into a conventional instructor role when students needed basic training in the use of technology and, moreover, when they needed to enhance the students' collaboration to support knowledge transmission between the teacher and the students.

Two teachers highlighted the fact that acting as a facilitator included asking questions rather than giving answers. One of them said, "*I give them time, and they can come to me if they need help or questions, and I can also ask questions that make them think about their own work. Or I can point them in directions that might make sense".*

The teachers said they were also aware of not executing the students' tasks for them and guiding them further in the creative process by discussing and sometimes limiting their options. "*[Sometimes] I'm there to limit them. If I see that they are thinking they are going to build something that is completely impossible, then I help them to limit their options so they don't feel that their idea is bad but that they get a small variation or almost what they thought".* Furthermore, the teachers focused on allowing students to reflect on various challenges, with these reflections occurring individually or within groups.

One of the teachers mentioned that it could be somewhat chaotic in the classroom when students worked independently or when he changed his role to that of facilitator: "*A challenge there is that it can get a bit chaotic, especially at the start when there are many people who don't know where to start".* Working in this way could also be tiring, but the teachers said the students became more independent over time.

Discussing the findings

Defining creativity and makerspace

All of the teachers similarly defined the term *makerspace* as a place where students utilise their creativity and make things. A makerspace was further described as a place in which students can experience mastery in a different way than in a theoretical study in a typical classroom. The teachers offered many useful conceptions of creativity and emphasised creativity as being something new and different that could be learned. However, although the teachers' conceptions of creativity were simple, they differed. For example, some teachers used the terms *creativity* and *innovation* synonymously, some emphasised technological knowledge in a makerspace as a base for creativity, and others talked about the importance of combining knowledge from different school subjects. This could indicate that these teachers had different understandings of creativity, which could affect their teaching approaches and, consequently, students' creative development (Davies et al., 2013). These results are consistent with Olafsson (2020) findings that teachers' understandings of creativity are different in many ways and, consequently, they use different teaching methods to train students. Furthermore, teachers may be capable of creativity, but their knowledge level and work environments may discourage it (Bereczki & Kárpáti, 2018). Using conceptual models such as Amabile's (2013) componential theory, therefore, would help teachers conceptualise and support student creativity. For example, of Amabile's four components, the teachers mentioned *domain-relevant skills* and *creativity-relevant skills* more often than *task motivation* and the *social environment.* Nonetheless, according to Amabile, all of the components should be emphasised to support creativity (Amabile, 2013).

The teachers said they believe that the ability to be a creative maker is developed through the students' work in the makerspace. However, the teachers' understandings of creativity may have affected their design of the makerspaces and, as a result, their teaching. Several researchers have recognised makerspaces as inclusive places that support hands-on learning through the use of highly technical tools and low-structure materials (Hakkarainen & Seitamaa-Hakkarainen, 2023; Loertscher et al., 2013). These places can foster creativity, interpersonal communication, teamwork, problem solving, critical thinking, and professional skills in groups of makers (Peppler et al., 2016). Therefore, the makerspace design should also set the stage for constructive teamwork and a positive social environment. However, the teachers interviewed placed little emphasis on the social environment despite the fact that research has found student interaction to be critical for enhancing creativity in makerspace settings (Giannakos et al., 2017; Bower et al., 2020). Furthermore, a positive makerspace culture also motivates students to innovate and enhances their self-perception and creativity (Carbonell et al., 2019). This does not mean that the teachers who were interviewed do not have good practices to support students' creativity, but there is room for improvement regarding their conceptual understanding. A better understanding of creativity could improve the design of makerspaces and related teaching practices.

Makerspaces to foster creativity

Some of the teachers in this research based their work on ready-made kits, while others focused more on open-ended creative processes. Maker-centred learning is based on social constructivism and is aimed at fostering makers' capacities for observing closely, exploring complexity, finding new opportunities, and creating future conditions (Clapp et.al., 2016). If the teaching is based merely on ready-made kits, the activities are related mostly to learning new technology and problem solving in the context of finding pre-defined solutions. Furthermore, the teaching methods often become more instructional. The processes of problem solving and idea generation lie at the core of both invention and design (Van de Ven et.al., 2000). However, a creative process is much more than problem solving and must progress beyond ready-made kits with pre-defined solutions. Furthermore, preparing students for participation in the 21st century requires open-ended creative processes with many possible solutions. Many academics, according to Robinson and Aronica (2015), consider that creativity has the power to change and reimagine education. They have observed that the traditional methods of "factory model classrooms" and assessment-driven learning have prevented young students from being creative and, instead, have focused on high-stakes tests. The use of digital technology in makerspaces can scaffold creative learning and plays a vital part in preparing students for the future (Van Lar et al., 2017; Glăveanu et al., 2019). Furthermore, it helps students create new knowledge by participating in inventive practices and "making" (Halverson & Sheridan, 2014). A few of the interview respondents highlighted the importance of fostering student creativity using digital technology, and working with manual and digital technologies was believed to increase students' motivation levels. Moreover, digital tools utilised in makerspaces were considered helpful for students' learning and their future working lives. However, supporting knowledge creation and creativity requires teachers go beyond the use of ready-made kits and enable students to participate in open-ended creative processes.

One of the goals of makerspaces, according to some of the teachers, is to educate children in how to participate in flexible creative processes. These teachers placed less focus on ready-made kits and more on open-ended design tasks or problem-solving assignments. For instance, these open-ended creative processes aimed to teach students to be flexible, take risks, persist, be independent, feel free to make mistakes, and embrace uncertainty in the creative process. Some teachers said they believed the students' results were not very creative, that their pupils had only worked to make prototypes as the outcome of the activity. Nevertheless, teaching methods that focus on problem solving, design, and innovation can be used in makerspaces or in learning units that combine several subjects. Such teaching pushes students to find new ways to solve problems in which they learn through the process of creative knowledge construction (Sawyer, 2012). Furthermore, students' knowledge acquired through an open-ended design task will contribute to their development and enable creativity.

However, the teachers also noted that time became a concern. Too much time was spent on learning to use the technology, such as programming, before students could begin their own three-dimensional creations, leaving insufficient time for the completion of other tasks. Nevertheless, several teachers realised that students might learn by creating objects and solving problems; therefore, these processes enable future creativity. The Norwegian core curriculum emphasises creativity and innovation (Kunnskapsdepartementet, 2017), but the curricula for various school subjects (UDIR, 2019) do not seem to provide sufficient room for working with creative processes (Dale et al., 2011). According to Halverson and Sheridan (2014), students generate new knowledge via creative thinking and making. Therefore, spending more time in the makerspace could give students opportunities to utilise their knowledge and skills to learn different core subjects through engagement in creative processes.

The teacher's approach in makerspaces

Most of the teachers stated that their approach in a makerspace differed from their traditional classroom approach. They felt the necessity of assuming multiple roles and of being observers and facilitators rather than instructors. Clapp et al. (2016) stated that a teacher's main role in a maker-centred classroom is to be a facilitator. However, some of the teachers argued that they must also give students basic training in the use of technology and, thus, they alternate between the roles of instructor and facilitator. This is in line with the findings of Smarason et al. (2021), that the teacher's role varies from direct instruction and offering advice to modelling behaviours and coaching or mentoring. Nevertheless, Heinze (2008) argued that the conventional teacher-centred role in which knowledge is "transmitted" from the teacher to the learner should be augmented by alternative models, and the focus should be on supporting and guiding students in a classroom where the roles of teachers and students are similar, and the communication is open (Jonsdottir & MacDonald, 2011). Therefore, learning basic skills could be done through creative processes in which teachers facilitate rather than instruct (Sawyer, 2012).

Makerspace activities can be recognised as learner-centred, and any activities can be described as constructivist and socio-cultural (Blikstein, 2013; Bonk & Cunningham, 1998). Teachers in a makerspace would benefit from creating circumstances that scaffold the students' creativity and provide a source of information that facilitates their activities (Vygotsky, 1978). In this research, the teachers envisioned their role as someone who asks questions rather than provides answers, who does not carry out the assignments given to the students, and who guides the pupils further into the creative process through discussion. These teachers' approach, therefore, supported the students' knowledge construction. Furthermore, two of the teachers said they were aware of the role of constraints in fostering students' development and creative thinking, adding that they thought it was difficult to begin a project or produce ideas when there were no restrictions. Research on creative ideation (Medeiros et al., 2014; Rietzschel et al., 2014), product development, design innovation, and engineering design have all documented the facilitative effect of constraints for enhancing student creativity.

One teacher stated that disorder was a possibility in the classroom when students worked independently and when the teachers switched back and forth from being instructors to facilitators. The students, moreover, sometimes became tired because they were not used to working independently. It is likely that the novelty of being inside a makerspace in a different teaching and learning context meant that the students needed time to adapt to this new educational context with which they were unfamiliar and to establish their new study behaviours. Transforming education to stimulate students to be creative (Robinson and Aronica, 2015) will require investments of time from both students and educators, and makerspaces can be an important part of that transition. Furthermore, student-led collaborative environments should be the driving force in a maker-centred educational setting (Korhonen et al. 2022).

Conclusion

The teachers' understandings of the term *makerspace* as a place where students use their creativity to make things were similar. However, their understandings of creativity differed, and these variations could affect their concepts and their uses of makerspaces (Bereczki & Kárpáti, 2018; Olafsson, 2022). Some teachers focused on ready-made kits to encourage problem solving and used conventional teaching methods to establish technical knowledge and skills rather than fostering open-ended creative processes. Consequently, students worked less with their own ideas. Assessment-driven learning and old-fashioned art education appear to be the driving forces of education and may prevent young students from developing their imaginations (Robinson & Aronica, 2015). According to some of the interviewed teachers, their students had to spend too much time learning how to use new technology, which prevented them from gaining new knowledge by creating objects and solving problems (Halverson & Sheridan, 2014).

Nonetheless, according to some of the teachers, the use of digital technology enabled and stimulated the students' creativity and learning (Cachia & Ferrari, 2010). Regarding their work with innovations, the teachers also saw this use of technology as a means of helping students build 21st-century capabilities (Van Lar et al., 2017; Glăveanu et al., 2019). However, none of them mentioned the importance of incorporated ideas of Education for Sustainable Development (ESD) and Global Citizenship Education (GCED) into the makerspace pedagogy to assist students in acquiring values, attitudes, and abilities that will benefit humanity not only in the twenty-first century but also in the future (Cleminson, 2021).

Some teachers also noticed that the students' motivation levels increased during their time in the makerspaces, and they attributed this enhanced motivation to teamwork, design work, and the use of both manual and digital tools (Bower et al., 2020; Giannakos and Jacherri, 2018). The teachers offered many useful ideas about creativity. However, they would benefit from using conceptual models such as Amabile's (2013) componential model, which would allow them to consider additional aspects of creativity when organising their classroom and planning their lessons.

Most of the teachers observed that their work supporting creativity in a makerspace differed from that in conventional classrooms. Rather than being traditional teachers, they believed they needed to play a variety of roles, such as observers and facilitators (Clapp et al., 2016). Additionally, they felt the need to alternate between being an instructor and a facilitator according to the requirements of each individual student (Smarason et al., 2021). In addition, they said teachers must provide information that supports the students' activities and allows the makerspace to enable their creativity (Vygotsky, 1978). The results of this study also indicate that teachers struggle to strike a balance between teaching students to use the makerspace equipment and supporting their creativity when doing so. Integrating makerspace activities in a student learning environment from a young age would give students the time necessary to learn how to use the makerspace's digital and non-digital equipment and, thus, enhance their later ability to work with open-ended creative processes.

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