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Teachers' pedagogical beliefs in Norwegian school makerspaces

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Abstract

In Norway, makerspaces are emerging as new educational contexts across all school levels. This trend is multifaceted as it is inspired by the global maker movement and supported by local initiatives as well as a national policy to create more opportunities to teach digital competencies. The makerspace concept facilitates this in a concrete and innovative way. Although the maker movement is established, the pedagogical foundations of maker activities in educational settings are still being developed. As the movement meets competent teachers and existing learning cultures, there is the potential to create new pedagogical knowledge and educational practices. This study explored teachers' values and beliefs regarding maker-centered learning in Norwegian schools through qualitative semi-structured interviews with maker teachers from 18 schools. The results indicate that makerspaces in Norwegian schools are initiated and driven by teachers' interests in the maker movement, which resonates with their learning beliefs. The individuals in question are mostly natural-science teachers inspired by other makers. The learning culture in Norwegian schools, and that found in the maker movement, coincide in many areas. However, there are some compatibility challenges, such as facilitating open-ended learning processes and initiating learning frameworks that allow students to act and learn based on their motivations and ideas. With guidance from the latest curricula, teachers are encouraged to teach toward learning goals, which have been traditionally achieved with structured and predefined activities. In this goal-directed environment, maker teachers struggle to find room for iterative processes, play, and productive failures.

Keywords Makerspaces · Teachers' pedagogical beliefs · Maker-centered learning

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Introduction

This study examined the pedagogical beliefs and values of educational-makerspace teachers in Norway. Over the past decade, makerspaces and maker activities have emerged globally within and outside educational contexts (Blikstein, 2013; Halverson & Sheridan, 2014; Papavlasopoulou et al., 2017; Schad & Jones, 2020). Makerspaces are a crucial component of the larger maker movement, which includes do-it-yourself culture, maker events, and was originally promoted in publications such as *MAKE Magazine* (Hatch, 2013; Vossoughi & Bevan, 2014). The development of digital-fabrication technologies has enabled students of all ages to invent, design, and make complex artifacts (Blikstein, 2013; Papavlasopoulou et al., 2017; Riikonen et al., 2020a). A makerspace serves as a unique platform to produce inventions in schools and promote interdisciplinary learning in the humanities, crafts, and STEAM disciplines (science, technology, engineering, art, and mathematics). Recently, makerspaces have also emerged in many Norwegian schools, from primary schools to higher-education institutions. This trend is multifaceted as it is supported by various initiatives, with the natural sciences, science centers, technical museums, Skaperskolen, and STEM disciplines at the forefront of this phenomenon (Høibo, 2023). The development of makerspaces in Norway is also supported by a national policy aimed at creating more opportunities to teach digital competencies. Although research on makerspaces has increased rapidly, maker pedagogy is still a new field of study, and little is known about teachers' approaches to such pedagogy and makerspaces. Therefore, it is necessary to better understand how educational makerspaces can be further developed (Bullock & Sator, 2015; Kjällander et al., 2018; Walan & Gericke, 2023) and how they fit into existing pedagogical infrastructures, beliefs, and values.

Maker pedagogy has its theoretical origins in Seymour Papert's (1993) constructionism, which emphasizes the importance of the novel learning pathways that are opened when students design and invent artifacts under guidance (Blikstein, 2013; Kafai, 2015). The central concept of constructionism is the "object-to-think-with," according to which hands-on working with artifacts engages learners in personally meaningful creative projects. Papert (1993) argued that technology should not be used to optimize teaching and learning; instead, it should give children the knowledge and skills to influence the digital development of society. Students' agency is seen as critical, and they should be given control in the process of shaping digital and analog objects (Papert, 1993). Learning by making is the core principle of constructionism; it highlights the importance of developing an idea and designing and creating an external representation of it. Constructionism focuses on how the making of artifacts supports learners' conceptual understandings.

The pioneering efforts of Papert and his followers have played a crucial role in establishing maker pedagogy. We use this term to refer to all kinds of maker-centered learning settings that utilize traditional and digital technologies and in which the focus is on giving students the opportunity to create something with their hands (Clapp et al., 2016). Maker-centered learning builds on student-active and material-based pedagogies in which social interaction and interaction with materials, tools, and technologies foster creativity through artifact-mediated making processes (Bevan et al., 2015; Clapp et al., 2016; Riikonen et al., 2020a). Makerspaces offer collaborative environments and interdisciplinary projects that encourage open-ended processes for creative ideation and innovations. Maker activities are based on nonlinear processes in which the required knowledge and solutions cannot be determined beforehand but emerge interactively through repeated personal and collaborative efforts (Hakkarainen & Seitamaa-Hakkarainen, 2022). As stated by Blikstein (2013), digital fabrication and making in schools could represent an unprecedented opportunity for teachers to advance a progressive educational agenda in which project-based, interest-driven, student-centered learning is at the center of students' experiences.

However, when maker culture is taken into a formal school setting, there is the need to combine different pedagogical views. Smith et al. (2016) found three challenges that impacted teachers' options for integrating maker practices into formal education: (1) teachers' lack of experience with complex design and making processes, (2) their challenges in managing digital technologies and design materials, and (3) their challenge with balancing different modes of teaching. Thus, to combine digital technologies and formal education, teachers need new approaches, skills, and practices (Smith et al., 2016). Furthermore, Rouse and Gillespie Rouse (2022) discovered tensions related to school-based and out-of-school makerspaces. These tensions are to do with the goals and objectives, scope, teaching and teacher role, in schoolbased makerspaces but that differ from the more free makerspaces. They also found that makerspaces are usually seen as distinct from structured, formal learning environments and that developing maker-centered learning does not depend on teachers having sophisticated socio-digital competencies; it relies more on the opportunities provided by the curriculum and the schools' individual infrastructures and practices.

This article analyses the pedagogical beliefs and values concerning maker-centered learning held by Norwegian educational-makerspace teachers. In the latest Norwegian school curricula, practical, student-active, creative, interdisciplinary, and explorative approaches to learning are strengthened, which is much in line with the maker-pedagogy approach. At the same time, the number of makerspaces is continually growing and is supported by several national initiatives (Erickson et al., 2018; Kjällander et al., 2018). However, there are no clear and uniform guidelines on how makerspaces should be integrated into formal school settings. Currently, it is up to each school and its teachers to decide how to do this. In Norwegian schools, therefore, teachers' personal engagement and beliefs play a key role in the pedagogical decisions regarding whether and how makerspaces are used in teaching. Hence, we asked the following research question: *What characterizes teachers' pedagogical beliefs in Norwegian schools' makerspaces?*

In the following section, we briefly describe the overarching values and principles of the Norwegian curriculum, as well as the related pedagogical beliefs concerning basic education. Then, we review previous research on teachers' pedagogical beliefs about maker pedagogy. Next, we outline the research context, data collection, and data analysis, and we discuss the findings. Finally, we present our understanding of Norwegian teachers' pedagogical beliefs regarding educational makerspaces and what challenges and opportunities they see in them.

The values and principles of basic education in Norwegian schools

Competent teachers possess both professional and pedagogical skills as well as cultural values and convictions. However, their roles have been fundamentally challenged and changed by the encounter with educational makerspaces. At present, teachers need new capacities to design and carry out maker activities in formal school contexts (Andersen & Pitkänen, 2019).

In Norway, the basic-education system consists of primary education (ages 6–12), lower-secondary education (ages 13–15), and upper-secondary education (ages 16–18). For the past 20 years, the curriculum emphasized verbal and theoretical subjects; however, the most recent version, introduced in 2020, shows a stronger emphasis on craft skills, practical learning, and exploratory working methods (Borgen et al., 2023). The vision for basic education is set out in the general part of the 2020 Education Act, and it describes what should characterize pedagogical practices and the development of students' competence during education as the "joy of creating, engagement, and the urge to explore"; it also emphasizes students' "opportunities to be creative, committed, and curious" (Utdanningsdirektoratet, 2017, pp. 3–7). In the Norwegian curriculum, the active and creative student is portrayed as an ideal in the learning process, and practical-aesthetic subjects are seen as the way to reach this educational ideal, with creativity and making being aspects of all school subjects. Furthermore, the Norwegian curriculum encourages practical-aesthetic subjects to be furnished with digital tools to develop digital competencies (Kunnskapsdepartementet, 2017a, 2017b).

These curricular values are similar to the maker-centered learning approach; the similarities include the emphasis on playfulness, collaboration, creativity, practical activities, and aesthetic forms of expression. The concepts of maker culture, makerspace, and maker-centered learning encompass a comprehensive view that praises the essential principles of creative curiosity, problem-solving, persistence, and confidence (Chu et al., 2015). Maker-centered learning is closely connected to practical-aesthetic subjects, such as arts and crafts and technology education (Ericsson et al., 2018; Korhonen et al., 2022). The overall approach to learning in Norwegian basic education shares many ideas with maker-centered learning, including artifact-mediated learning through making, 21st-century skills, active engagement and exploratory learning, the inclusion of new technologies, and the development of digital skills. However, when aiming to facilitate open-ended teaching and learning, there are some obvious differences and obstacles. When learning goals are structured toward predefined outcomes and products, it is difficult to provide room for iterative processes, playfulness, and productive failures (Sawyer, 2018).

Teachers' pedagogical beliefs and teaching in maker-centered learning settings

In the deepest sense, pedagogical beliefs refer to the basis and values behind teachers` pedagogical choices. They are the principles underlying teachers' learning philosophies and knowledge construction (Mishra & Koehler, 2006). Pedagogical beliefs are not permanent; they are dynamic and constantly evolving. They cover teachers' beliefs about teaching and learning but also ideas for how to improve the learning settings. Teachers work both at the back and at the front—they design learning with long-term goals and objectives, but they also act in situ, making quick decisions to facilitate students' work. Every day and in every situation, teachers make small choices related to which materials, tools, and guidance should be used. Teaching is thus a highly complex activity that draws on many types of knowledge (Mishra & Koehler, 2006). With the advent of digitalization, new technologies have become yet another component of teaching and learning. Mishra and Koehler (2006) developed a framework for studying how teachers integrate digital technology into their pedagogies. The technological pedagogical content knowledge framework views learning environments as consisting of three components: content knowledge, pedagogical knowledge, and technological knowledge. The framework offers a language with which to describe these three components and the connections between them that are present (or absent) in a school makerspace and the teachers' pedagogical beliefs.

The maker movement and its culture strongly contribute to the maker identity and maker mindset, which include resilience, curiosity, confidence, persistence, and resourcefulness

(Cohen et al., 2018; Dougherty, 2013). Furthermore, maker activities aim to advance agency and authorship and encourage risk-taking and iteration; they can also lead to both frustration and excitement (Blikstein, 2013) According to Clapp et al. (2016), teachers play a key role in supporting the formation of maker mindsets in formal education. Hjorth et al., (2016) argued that maker pedagogy also requires a change in teachers' mindsets, capabilities, and pedagogical beliefs that encourages the implementation of digital technology and new teaching practices. Implementing maker-centered learning in school makerspaces is challenging because it requires teachers to develop sophisticated digital competencies and cultivate novel pedagogical practices. It also requires a nonlinear pedagogy that asks students to create unforeseen solutions for ill-defined and complex challenges (Hakkarainen & Seitamaa-Hakkarainen, 2022). Dealing with uncertainty in the creative process is necessary, but it is also challenging for the teachers, who must be able to smoothly adapt to emergent ideas, unfamiliar technologies, and unpredictable situations. As indicated by Smith et al. (2016) and Andersen and Pitkänen (2019), teachers find it difficult to deal with digital technologies and complex design and making processes that are unfamiliar to them.

Hira et al. (2014) noted that teacher preparation is one of the challenges of implementing maker-centered learning activities in formal education because teachers need to find a balance between fulfilling learning objectives and preserving the unique aspects of maker-centered learning (see also Schlegel et al., 2019). Sawyer (2018) analyzed university teachers' pedagogical beliefs in art and design and found that teachers in arts and crafts to a large degree shared pedagogical beliefs despite different contexts and geographic locations. Makerspaces resemble these creative studio practices and share much of their cultural model of teaching and learning with craft and design disciplines (Sawyer, 2018). In maker-centered learning, the organization of pedagogical settings, the nature of the open-ended tasks, social organization, tools, and methods are carefully planned to enable the development of students' inventive skills. In accordance with studio practices, students are introduced to the process of working on open-ended but focused projects that meet external constraints determined by a design challenge (Sawyer, 2018). These projects prompt students to experience the complexity of the entire design and making process—defining the constraints, exploring and sketching ideas, and experimenting with various materials.

Pedagogical infrastructures

Ensuring that design and making activities lead to the intended learning outcomes requires pedagogical planning as well as engagement and facilitation of the process by the teacher. Teaching and learning situations consist of many components, such as the traditions and culture of the school, daily school rhythms, teacher facilitation, spatial arrangements, materials, and technological tools and resources (Lakkala et al., 2010). In maker-centered and collaborative settings, the emerging processes and outcomes are strongly shaped by the joint activities and interactions of the participants; therefore, they cannot be defined and designed in advance (Lakkala et al., 2010).

In an educational context, there is always a pedagogical infrastructure that mediates these kinds of cultural practices and guides learners' activities (Lakkala et al., 2010). The term "pedagogical infrastructures" refers to the designed arrangements and underlying conditions necessary to implement the technology-mediated learning needed for reaching educational objectives during classroom practices. As stated above, the idea of a makerspace highlights the specific studio context of creative arts and crafts practices, which entails designing open-ended, individual, or collaborative learning challenges (tasks) and working with a variety of tools and materials (Sawyer, 2018; Seitamaa-Hakkarainen, 2022). This framework allows us to examine which pedagogical infrastructures support and build on maker-centered practices, as well as which components form the basis of a maker-centered approach to learning. A pedagogical framework consists of (1) an epistemological infrastructure (e.g., a pedagogical approach based on creative working and pedagogical principles for learning and teaching), (2) cognitive support structures (i.e., scaffolding that consists of the nature of the design tasks and models, which promotes students' competencies to work in the intended way), (3) a social infrastructure for ordering individual and collaborative activities (i.e., the social and physical arrangements for organizing collaboration and interaction), and (4) a material-technological infrastructure (adaptability to materials, tools, and technologies). In the present study, we used this pedagogical-infrastructure framework to characterize the participants' pedagogical beliefs and examine how epistemological, social, and material-technological infrastructures were highlighted in their interviews.

Method

This study is based on interviews with Norwegian teachers who conduct some of their teaching in educational makerspaces. In Norway, makerspaces in formal education are becoming more common; currently, there are 55 educational makerspaces registered in connection to, or inside, educational settings (norwaymakers.org). In addition, there are several such spaces that do not identify as educational but that nevertheless engage in maker-oriented learning, together with all those that are not included in the abovementioned register. Norwegian maker-movement organizations have taken the initiative to provide overviews of active makerspaces, which has resulted in lists and maps of makerspace locations and affiliations. Based on these, we identified relevant teachers for our interviews. In addition, we followed suggestions from the maker community that we also contacted and included. The inclusion criteria were defining oneself as a maker teacher and operating in a makerspace located in a school. Most of the educational makerspaces we found were close to Norway's capital, Oslo, and the country's southwestern coast. Thus, we made an extra effort to find makerspaces from the northern, eastern, and central parts of Norway. In total, we contacted 24 school makerspaces found in different locations and operating at differing educational levels, and 18 agreed to participate. We encouraged our contacts to bring to the interviews colleagues closely connected to the makerspaces, and half of them brought one or two colleagues. This resulted in 18 interviews with 30 interviewees. Of these 18 interviews, 12 were individual; 2 were conducted with pairs of teachers, and 4 were group interviews with 3–4 participants. Both pair and group participants were working in the same school. All the teachers in the group interviews were active, and we made extra efforts to get all the voices represented in the answers. It was important to include a high number of makerspaces and teachers to obtain a complete picture of Norwegian school-based makerspaces. So far, our study is the most comprehensive overview of the activities and attitudes of Norwegian educational-makerspace teachers.

The 30 participants were evenly distributed between men and women (16 men and 14 women). The interviews were conducted in 2022 and 2023. Seven makerspaces were in upper-secondary schools (ages 16–18); four were in lower-secondary schools (ages 13–15), and five were in primary schools (ages 6–12). Two schools offered both primary and secondary education. The inclusion of all educational levels led to some challenges when comparing teachers' beliefs and pedagogical approaches. However, many of the participants looked at education holistically and considered themselves to be educating students toward becoming citizens of the future world, regardless of their ages. The inclusion of all educational levels also provided a unique opportunity to highlight similarities and differences in makerspaces related to the different levels of basic education.

The semi-structured interviews consisted of five main themes: (1) the backgrounds of the teacher and makerspace, (2) how the makerspace was used, (3) the concepts of creativity and maker mindset, (4) the planning and implementation of teaching in the makerspace, and (5) student assessment. The aim of the interviews was to listen to the teachers' voices concerning their pedagogical values, beliefs, and teaching activities in the makerspaces. We emphasized that the participants should describe how and why they taught in certain ways in the makerspaces. The interviews lasted around 1 h, but the group interviews took longer. All the interviews were transcribed in full. To examine the data, we used both inductive and deductive thematic analyses (Fereday & Muir-Cochrane, 2006).

Since the interviews were long and multifaceted, there was a need to classify the data. Therefore, we started by deductively organizing the data with a set of codes based on our research question and theoretical framework, mainly using the four categories of the pedagogical-infrastructure framework. The *epistemological infrastructure* referred to how the teachers saw the epistemic processes of maker-centered learning—that is, the iterative, nonlinear, open-ended processes that develop students' maker mindsets. The *learning scaffolding* was related to the teachers' facilitation, designed tasks, and project activities. The category of *social arrangements* pertained to how students' work and interactions were organized. Finally, the *material-technological infrastructure* was related to various digital and traditional tools for designing and constructing, as well as their appropriateness for the desired activity (Riikonen et al., 2020b). During the first round of analysis, some additional categories emerged from the data, such as the phenomenon of enthusiasts, teachers' motivations, and the entire learning progression. Based on these new themes, we carried out consecutive in-depth inductive analyses through condensed and thick descriptions (Tjora, 2018). The coding was conducted with NVivoTM, a qualitative-content analysis program with which a large amount of data can be easily categorized, combined, and merged in multiple ways. This allowed us to produce a concise view of the participants' pedagogical beliefs.

Findings

Backgrounds and motivations

The teachers who participated in our study were often enthusiastic individuals with curious, fearless approaches and strong resilience. They generally had solid academic and pedagogical backgrounds, and they were mainly science teachers. Many of them had specializations in information and communications technology (ICT); most of those with vocational/ICT education worked at the upper-secondary level, whereas those with pedagogical ICT education were primary-school teachers. The natural-science initiatives of the Skaperskolen together with the country's science centers and technical museums can partly explain the predominance of science teachers in our sample. Of the 30 individuals we interviewed, only five were arts and crafts teachers, and they were represented at all three levels of basic education. The teachers' seniority ranged from recent graduates to knowledgeable individuals with more than 20 years of teaching experience. At the upper-secondary level, some of the participants used to work in practical professions before switching to the educational sector midway through their careers. These individuals usually taught vocational subjects, such as computer science, electricity, mechanics, and other industrial subjects.

At the various levels of education, there were differences in the frameworks and support structures used in educational makerspaces. In primary schools, science and mathematics lessons were mostly linked to makerspaces, although some arts and crafts lessons also were. Several teachers had created a separate subject called "makerspace," "programming," or "coding." In the lower grades, some schools set aside weekly hours for makerspace-related activities. These hours were not linked to a specific subject, but the tasks students worked on during them often had content from the natural sciences, social sciences, mathematics, and sometimes from arts and crafts. One school had created what they called "makerbreaks," open-door events held during longer breaks between lessons. Makerbreaks were optional. During them, students could do self-initiated projects under guidance. At the secondary level, makerspace activities were frequently linked to the elective course Technology and Design; some were also linked to Media and Communication and Programming. At the upper-secondary level, interdisciplinary projects were well represented, especially in the subjects Technology and Theory of Research as well as Pupil Enterprise. At this level, makerspaces were also directly connected to the content of vocational courses dealing with topics such as electronics and computer technology, technology and industrial subjects, programming, media and communication, crafts, design and product development, and art, design, and architecture.

Most of the teachers had no specific time allowance set aside to run the school makerspace, but they did it anyway, often in their free time. Their strong motivations were revealed when they told us that running the educational makerspaces depended entirely on them and that doing so was a lifestyle choice for them; they would do anything to maintain such spaces. These individuals were enthusiastic about the maker movement and found that it resonated with their pedagogical beliefs. Surprisingly, their general pedagogical beliefs concerning makerspaces and their practices were similar regardless of what level of students they taught. In addition to their strong belief in the maker-centered approach to teaching and learning, they were also interested in technology and making, which they considered important, exciting, and fun. Many of them did maker activities and worked with maker tools themselves. They described their personal projects to us, as well as the workshops and tools they had at home (e.g., 3D printers, vinyl cutters, and soldering stations). For these individuals, it was motivating to teach these skills to their students and figure things out with them. They believed that students' commitment to learning should be based on joy and intrinsic motivation. A female participant teaching primary pupils stated, "It is a paradox that little ones like school, but then the joy and creativity disappear as they get older." The participants also believed that there was a need for more relevant activities in school to meet children's requirements for social development and the reality they faced outside. They emphasized that it was important to closely follow interested and talented students who wanted to learn more, which is why they were willing to spend their free time on bigger school projects. Another female primary-school teacher underlined an aspect that many participants mentioned, namely that it was important "to take learning out of the books and programming out of the screens and let the children be practical and make things." Several teachers also mentioned some of the aims of the new curriculum, such as creative joy, interdisciplinarity, in-depth learning, and programming. Upper-secondary level teachers were concerned with the placement of apprentices and the learning that prepared pupils for adulthood after finishing school.

Epistemological infrastructure: knowledge creation through making

We were interested in the epistemological infrastructure that highlighted maker teachers' approaches, how they viewed nonlinear maker-centered learning processes, and what they considered the main aim of educational makerspaces to be. Even though Papert's ideas (1993) shined through in the ways the participants dealt with knowledge creation, few of them referred to him. In general, they rarely mentioned the pedagogical theorists of the maker movement. When we asked more directly about this topic, several teachers referred to John Dewey and learning by doing, while others mentioned Vygotsky's zone of proximal development. Some of them pointed out that the national curriculum had important guidelines for developing 21st-century skills, such as creativity, collaboration, and problem-solving. However, most said that they did not follow specific pedagogical theories. In essence, these teachers believed in learning through making, and this applied both to students' learning and their own learning and development.

Furthermore, the participants' pedagogical beliefs were grounded in something more general than achieving specific academic-curriculum goals. When the teachers spoke about teaching and what the pupils learned in the makerspaces, they soon mentioned the wish to form whole persons so that the students could manage in society. The participants talked about cognitive fitness (i.e., being open to new ideas and alternative perspectives), collaboration, innovation, problem-solving, and exploration. They also spoke about letting students create, teaching them to take the initiative, and giving them self-confidence by letting them try and learn by constructively failing, and figure things out on their own. A male upper-secondary level teacher said, "It is about them learning to be responsible and independent by not telling them all the secrets." A female teacher from a lower-secondary school explained the following:

> Academically, they will not necessarily learn based on our competency targets and things like that, but they will learn to trust themselves. They learn to try their best and not to give up, and that is mastery of life at its best.

This is very much in line with the constructionist view of learning, according to which education should take responsibility for the whole human being, with their complex abilities, needs, and potentialities. These are the aspects that learning and teaching in makerspaces should accommodate (Blikstein, 2013; Clapp et al., 2016). Thus, the participants' epistemological views highlighted art- and design-based knowledge creation as a *nonlinear and emergent process* (Härkki et al., 2021; Riikonen et al., 2020b; Sawyer, 2021). They also conceptualized learning by making as supportive of creative engagement, resilience in overcoming obstacles, and the development of a sense of being a future creative contributor.

The teachers we interviewed found confirmation for their maker activities in the learning objectives of the various school subjects. However, they experienced a contradiction between helping students to explore based on their motivations (as highlighted in the general part of the curriculum) through problem-based and process-oriented tasks and achieving the learning objectives of the subject-specific parts of the curriculum. These aspects were related to the *scaffolding of the learning and designing*, which involved the nature of the design tasks, the structures of epistemic scaffolding for promoting students' capacities to engage in nonlinear and iterative processes, and the guidelines relevant to the scaffolding of the designing. Some of the participants said that teachers, especially those who are not maker teachers, find it difficult to achieve set learning objectives through makerspace projects. Many of the participants also said that the main goal of maker projects was to facilitate student-initiated and open-ended tasks; however, students needed to master several basic skills before teachers could give them a free hand. Therefore, especially in primary schools, some teachers made step-by-step plans for each year, determining what pupils should learn in the makerspaces. They started with basic techniques and materials and reached open-ended tasks only toward the end of primary school. The same tensions have been documented in previous studies in which teachers found it difficult to maintain co-construction and flexible design processes in tight school structures with time constraints (Rouse & Gillespie Rouse, 2022).

Several participants highlighted that there was less focus on craftsmanship in makerspaces than in traditional arts and crafts. A male maker teacher working in a lower-secondary school said, “What is important in makerspaces is getting the students to be independent. The point is that they should own what they are doing.” Many of the participants argued that it was difficult, on the one hand, to give students freedom in creative learning processes and, on the other hand, to ask them to reach definite learning goals. A male maker teacher from a lower-secondary school exemplified this problem with the typical arts and crafts task of carving a spoon. He said, “All the students do the same thing. Some may produce a spoon of 10 cm, while others may have a spoon of 7 cm, but it is still the same recipe for the same goal.” Maker teaching and learning were seen as different approaches because, with them, students were free to decide *what* to make. Instead of telling pupils to make a spoon, a makerspace task involved them making something that had that function. What the students would end up with would largely differ. In the arts and crafts subject, the participants were concerned with the contradiction between the open-ended maker tasks and the need for students to learn craft skills properly, how to use tools and techniques, and how to work with different materials. However, this was not the case for the science teachers, who emphasized problem-solving regardless of specialist material skills.

The interviews revealed that the participants had fundamentally sympathetic views of their students. These views indicated a pedagogical belief characterized by respect, resonance, reverence, trust, and admiration, as well as a relationship grounded in care, equality, and humility. How the participants explained their teaching practices and learning beliefs, as well as how they followed their students in their faith, hopes, struggles, and dreams, expressed strong commitments toward them. Of course, this may apply to most school teachers, but in our opinion, these maker teachers were particularly dedicated professionals. This was evident in the degree to which they were inspired by learning from and with their students, and how important this part of the job was for them. At the same time, they highlighted how important the relationship and belief in the students is for building students’ confidence. A female upper-secondary school teacher said, “I do hope that if former students are in the area, they will come by and use the makerspace because they bring with them competencies we do not have.” Words such as these show that the participants believed in their students.

Social infrastructure: collaboration, scaffolding, and community learning

The social infrastructure and the practice of scaffolding students’ work were evident in the teachers’ interview responses. The culture of collaboration was apparent in how the participants trusted and respected their students as competent cocreators. This was expressed in statements such as the following: “I learn something new all the time” (female lower-secondary school teacher), “The students can build in Minecraft a hundred times faster than me" (male primary-school teacher), and "My incompetence should not stop the students" (female upper-secondary school teacher). A female primary-school teacher said,

> As a rule, the students always surprise me, and what they achieve turns out to be much more than what I had thought possible. Then, I feel a bit sorry for them because they had to go through my bad plan initially.

These statements show that the participants largely acknowledged their students as knowledge cocreators. They also trusted the collective and collaborative learning they could create together. The teachers carried out their learning and development based on the knowledge-building experiences they had with their students. They were willing to change their roles from omniscient teachers to companions who walked alongside the students in the learning community. As a male lower-secondary school teacher explained, "If I don't know the answer, I ask the students to try a little more, as long as it's not dangerous or too expensive."

The maker teachers believed in collaborating with their students across subjects, ages, and classes. However, they did not explicitly mention the practical organization of *social infrastructure*, including what kind of physical and social arrangements were in place to organize students' collaboration, productive teamwork, and social interactions. Instead, they offered deep insights into various aspects of group work, such as, shared responsibility, and how important it was to create groups with different competencies and social skills. As a female primary-school teacher said, "Sometimes, you also need the little brake, the realist who can assess whether the idea can be carried out." In addition, the participants talked about the need for the students to listen and try to understand what someone else had in mind concerning the idea that had been presented. As a female primary-school teacher put it, "They shouldn't only be concerned with their ideas and be unable to hear what others are thinking." The participants spoke to the students about the importance of creating together and weaving ideas together. Several of them agreed that the ideal number of group members was small—two or three students. Some participants had feedback sessions at the end of their teaching sessions during which the entire group of 20 students could give feedback on each individual project.

The teachers' facilitation and scaffolding activities were also related to social infrastructures. Instead of instructing the students on what and how to do something through set presentations, almost all of them tried to get the pupils to learn by allowing them to do the work themselves. The key to this scaffolding practice was to give the students just enough basic skills, as one male teacher at an upper-secondary school explained. He said,

> First, you provide the basic building blocks for a subject or theme; then, you withdraw at the right time so that the student can continue to work independently. In this way, the student will own their project and their learning to a greater extent.

Another female primary-school teacher described her scaffolding with the following words:

> As a teacher and supervisor, you must be open to input. At the same time, you must have a plan for how things will end. Often, when I start a project, I have thought of a minimal solution so that we get some of it done.

For the participants, the teacher's role was to help, push, and ask questions rather than give answers. The teacher should also adjust ambitious projects, find tools and materials, and provide relevant information to students when they need it in their processes. Students should be allowed to tinker, try, and fail. When this happens, they should change something and try once again, until they get it right. The participants emphasized letting go of absolute control, starting projects that can fail, giving open-ended tasks, lingering in uncertainty, and daring to expose their lack of competence in certain areas. Several of the maker teachers had had good experiences using older students for peer tutoring; by doing so, the older students also reinforced their own learning. There was a slightly different approach between primary-school and upper-secondary school teachers. As stated by a male primary-school teacher, "It is more difficult to give freedom in primary school. The teachers must have tighter frames because young children require tighter control from adults."

The analysis also revealed that the participants tried to find knowledge and collaborators in communities of other makers beyond their school environments, both physically and online. More than half of them reported that they participated in networks (e.g., ICT groups) and attended relevant meeting places in their municipalities; they were also involved in entrepreneurial projects with local businesses. They took part in courses organized by science centers, technical museums, Skaperskolen, Norway Makers, and other makerspaces, especially those based in schools. Many of the participants were striving to create arenas in which young and old people could meet, which would provide people with opportunities to be part of communities. Therefore, some of the makerspaces in upper-secondary schools were open after school so that students and other people could meet and use their free time for school projects, socialization, and other leisure activities.

Nevertheless, there was a strikingly large group of teachers who reported that they were not part of any network. It was a challenge to get fellow teachers to believe that they had something to do in makerspaces. Many of the participants were used as resources at their institutions to engage other schools. Those who had support from management showed that this was a strength.

New technologies, tools, materials, and practical arrangements

The material-technical infrastructures of the schools in the sample appeared to be satisfactory. The participants had no problems in getting hold of new items of equipment for their makerspaces. They applied for internal and external funding, preferably through projects and other support structures. They also borrowed equipment from municipalities and science centers. Most of the teachers reported having access to 3D printers, electronics, vinyl cutters, soldering equipment, microcontrollers, sewing machines, and laser cutters. In primary schools, most makerspaces had variants of Lego and programming robots.

Despite having good access to a range of technologies, this is not what the participants emphasized when they talked about their approaches to materials and tools in makerspaces. Instead, they highlighted construction, creation, and how important material experiences were when making physical prototypes. This applied to printing 3D models or dismantling a car to see how it was assembled and understand each function. As one female teacher at an upper-secondary school said, "I think it's actually not even about technology; it's more about the attitude. But new technology has helped redeem this way of working." The participants stressed that the technology and novelty value of makerspaces had opened doors and provided opportunities in ways that traditional tools could not have done. Some of the teachers referred to subjects such as arts and crafts as representing traditional values that were the opposite of those spread by makerspaces. As a female upper-secondary school teacher said, "There are not as many conventions attached to the 3D printer as there are to traditional arts and crafts." This teacher also told us that young people often mastered maker tools more quickly than adults since they were more familiar with digital technology. This allowed them to gain ownership of their project, which was beneficial to their learning processes.

However, the participants made it clear that more traditional, analog tools should work side by side with the new ones. Several teachers said that the real goal was creating cross-disciplinary projects that combined tools when appropriate. They believed that learners should have easy access to tools and materials to get started quickly, as the real work was about materials and creation. According to them, tools and materials should be displayed on shelves and should be accessible to students so that all the options are available. Students should not be prevented from trying and failing because of fear of consuming expensive materials. One of the primary schools created a scrap library inspired by a makerspace in Denmark. In this library, they collected materials (e.g., cardboard, recycled resources, and old computers and mobile phones) that were freely available to the pupils. An upper-secondary school received the damaged fuselage of a glider. A group of students rebuilt it into a flight simulator, which was used for pilot training. A female maker teacher from this school explained their pedagogical beliefs thus: "Starting with simple tasks will hopefully pique students' interests; then, the learning path will be driven to a great extent by them." The participants emphasized that students should be educated to become digital producers rather than consumers and that both pupils and schools were involved in building the society of the future. The goal was to establish free, creative, student-initiated projects that used all the possibilities that makerspaces could offer as workshops.

Confronted challenges in makerspaces

The participants had few external incentives from the government and their schools; they were primarily internally motivated and enthusiastic. They could be described as almost idealists. This is because they saw the need for change in schools and had caught the essence of the maker movement, which they considered as a solution in how to meet the challenges they experienced in today's school. However, there were several challenges when embarking on open-ended tasks with students who lacked the necessary skills. There were also discrepancies between the set goals of the curriculum and the much freer goals of maker activities. This became evident when the light-hearted maker mindset met the more traditional values of arts and crafts education, which stresses the quality of materials, skills, and outcomes. Even though makerspaces share the same context and pedagogical tools as the subject of arts and crafts, their pedagogical values largely differ. This will be explored in a future article.

Assessment was also problematic, as the very idea goes against the ethos of co-creation and co-learning with teachers. This topic was raised in the interviews. Previous studies found tensions between maker-centered learning and standardized testing in schools (Peterson & Scharber, 2018; Walan & Gericke, 2023). In Norway, assessment with grades distinguishes between primary and lower-secondary school, where numerical grades are not set until in 8th grade, when the pupils are 13–14 years old. The participants at all levels mostly spoke of assessment as a formative evaluation and a supportive and progressive appraisal under guidance. This took place through subject-related discussions with teachers, as well as through feedback and progress reports aimed at motivating and engaging students and making them aware of what was expected of them and how they could improve. Several participants used student self-assessment and peer assessment on an ongoing basis to evaluate work in progress. A male teacher at an upper-secondary school said,

> I like to get them to predict what they think will be the biggest challenge going forward in carrying out what they have to do. … When you tell other students about the knowledge you have acquired and get recognition, it is much easier to register it as valid knowledge.

Almost all the participants expressed ambivalence regarding summative evaluations, especially those who graded their students' work. Several of them explained that they were strongly opposed to grades because they destroyed creativity and motivation and were inhibiting rather than encouraging. Several teachers also said that makerspaces should be free from rigid assessments. A female teacher at an upper-secondary school said,

> First, we learn together; then, we have to become separate actors and evaluate them. This creates a skewed power relationship that goes against the idea of a learning community where teachers and students work together toward the goal of knowledge. We sit with old knowledge, but we must encourage new knowledge. I assess from my old point of view, but I want people to move on.

Finally, many participants felt lonely at work, and their efforts, including their free time spent on maker projects, were not remunerated, an aspect that might threaten the long-term sustainability of makerspaces.

Conclusions

This study aimed to document the pedagogical beliefs of teachers working in Norwegian educational makerspaces. It examined maker teachers' pedagogical approaches and the infrastructure of maker-centered learning in terms of epistemological, scaffolding, social, and material-technical aspects. The participants were teachers at various levels of the school system. All of them were familiar with the values and pedagogical insights of maker-centered learning, and they had similar understandings of the maker mindset and teachers' facilitating role for students. The study found that most of the participants were science teachers. This is not surprising if we consider that at present, makerspaces in Norway have mostly been promoted by science centers, technical museums, Skaperskolen, and the natural sciences and STEAM disciplines (Høibo, 2023). We also found that arts and crafts teachers were largely reluctant to use makerspaces and be part of their schools' maker communities.

Several scholars have argued for the need to integrate maker-centered learning into formal curricula (Rouse & Gillespie Rouse, 2022; Smith et al., 2016; Walan & Gericke, 2023). However, very little is known about how makerspaces are run in schools, or about how curricula with formal goals support or hinder maker-centered learning. The present study found a shared view—makerspaces offer possibilities for creative projects that encourage open-ended and nonlinear processes where the solutions cannot be determined beforehand but emerge after social and material interactions. It should also be noted that the participants experienced a contradiction between open-ended maker activities and the standardized objectives of curricula and assessments. The wider concept of competence in the newest version of the national curriculum has created a path to teaching and learning in line with maker-centered pedagogical beliefs. Maker teachers have seized this opportunity, while arts and crafts teachers have found this change more problematic.

Implementing makerspaces in formal school settings requires fostering teachers' professional expertise, cultivating practices and methods of nonlinear processes, focusing on the essential aspects of curricula, developing new approaches to student assessment, and learning to use student diversity as a strength (Hira et al., 2014). These were all aspects of the pedagogical infrastructure that the participants were working with. Their epistemological beliefs highlighted that working on the challenges of maker projects supported students' creativity and resilience in overcoming obstacles; it also facilitated learning the true practices of STEAM disciplines. Furthermore, the teachers' facilitation and scaffolding infrastructure were divided. On the one hand, they highly appreciated students' autonomy; on the other, they wanted to give specific instructions to facilitate their agency. The participants needed to find the right balance between open-endedness and structures in projects (Sawyer, 2018, 2021).

The maker teachers in this study believed in a collaborative community of makers operating for knowledge creation; this community included students as cocreators of knowledge. Regarding social infrastructures, the participants talked about various aspects of groups, such as the promotion of shared responsibility in teams and the importance of forming groups with different competencies and social skills. They explained that the technology and novelty value of makerspaces provided more opportunities than traditional tools; however, such tools were also needed. Many of the teachers emphasized that makerspaces should contain a wide range of materials and tools—both digital and analog—and that they should be as accessible and open as possible.

The participants were highly motivated, and most of them belonged to communities of practice and networks where they could share their experiences, learn new skills, and receive pedagogical support and inspiration for their maker-centered teaching. The majority of them were also supported by their school districts and principals. The teachers were satisfied with the tools, materials, and spaces they used, and they had external financial support to run their makerspaces. Even though these maker teachers have started something promising, there is a need for a large community that works with them and ensures that more teachers feel welcomed and find room for their subjects in makerspaces. Acknowledging the pedagogical beliefs that underlie the teaching practices of different subjects and starting a discussion about these may help future teacher collaborations and include more disciplines in forming maker-content in school makerspaces.

The proactive engagement of teachers in makerspaces is an interesting development, which may foreground their agency. School owners have been responding positively to makerspaces as learning initiatives, and in some cases, resources have been allocated generously. However, more time and resources for individual professional development are needed to facilitate teachers' sustained engagement, as many of them currently use their free time for the activities in question. In this respect, more research on the support coming from parents, school administrations, and political decision-makers should be conducted.

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Declarations

Competing interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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