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Transferring makerspace activities to the classroom: a tension between two learning cultures

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Abstract
This case study aimed to investigate teachers' reflections on the transfer of makerspace activities into classrooms. Primary and secondary STEM teachers participated in a Continuous Professional Development programme about makerspaces. Data were collected in the form of written reflections and semi-structured interviews after the teachers conducted makerspace activities in their classes. A thematic approach was used for data analysis. The results showed that teachers identified possibilities: *Connections to learning objectives in STEM subjects; Motivating and engaging students; Stimulating collaboration; Stimulating creativity*; and challenges: *Problem of assessment; Lack of digital competence; Lack of high-tech equipment.* However, the teachers did not reflect upon the cultural, ontological, and epistemological differences between makerspaces and formal schooling. Thus, we argue that it is difficult 'to eat the cake and have it too', i.e. to fully reconcile both the maker-culture and demands of formal schooling. Rather, we suggest three ways to connect makerspace culture with formal education.

Keywords Classroom practices · Informal learning, Makerspace activities · STEM · Teacher reflections · Transfer

Introduction

During the last 10–15 years, the maker-culture has grown worldwide, and it is viewed as a way to allow young people to use new technologies in creative ways (Vuorikari et al., 2019). Much of the interest in the role of maker-culture in society has been on how makerspaces can fuel the next generation of Science, Technology, Engineering, and Mathematics (STEM) innovators (Honey & Kanter, 2013). The maker-culture can be described as an informal learning approach that promotes active participation, collaboration, and knowledge sharing among youngsters through open exploration and creative use of technology grounded in the learning theory of constructionism (Papert, 1993; Vossoughi et al., 2016). Makerspaces are often located in informal learning environments, such as museums, science centres, libraries, or industrial locations (e.g. Halverson & Sheridan, 2014; Peppler

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& Bender, 2013). However, there are also suggestions of transferring makerspaces/ makerspace activities to schools (e.g. Vourikari et al., 2019). In a recently published literature review (Rouse & Rouse, 2022), it was found that school-based makerspace research is increasing, and that outcomes and interventions vary considerably across different studies. However, Rouse and Rouse (2022) concluded that there is still a paucity of research, for instance, about best practices for makerspace teachers. In addition, it has been argued that academic analysis of makerspace activities in formal education sites is scarce (e.g. Papavlasopoulou et al., 2018; Tan, 2019). Hence, this study focuses on makerspace activities in formal education and teachers' reflections on transferring such activities to their classrooms.

There are several aspects to consider when integrating makerspace activities in schools, but the teacher's role is paramount; the teachers' perspectives are therefore the focus here. Earlier research has found a need for teacher training in the management of makerspace activities (Eriksson et al., 2018), since this is not part of basic training in teacher education programmes (Smith et al., 2016). Furthermore, teachers have reported problems in using high-tech equipment (Boeve-de Pauw et al., 2022; De Loof et al., 2019), and the need for support in how to support students in designing their own learning has been called for (Vuorikari et al., 2019). Because of these reported needs, we arranged a Continuous-Professional-Development (CPD) programme based on makerspace activities and invited primary and secondary STEM teachers to participate. A CPD programme is a systematic effort to bring about a change in teaching practices, in teachers' attitudes and beliefs and also in students' learning (e.g. Guskey, 2002). CPD programmes can be organised differently; as off-site programmes, school-based, university-school partnerships, etcetera (e.g. Luneta, 2012). The idea in our programme was to stimulate and support learning and to inspire the teachers to implement makerspace activities in their own lessons during the CPD. Teachers' experiences of transferring makerspace activities to the classroom were of prime interest; therefore, we posed the following research question:

> How do teachers' perceptions of the possibilities and challenges in transferring makerspace activities into their classrooms change after participating in a CPD programme?

Literature review

Characteristics of makerspaces

The first conceptualisation of makerspaces was made in 2005 (e.g. Cavalcanti, 2013; Martin, 2015); they are characterised as environments where digital fabrication (e.g. Davies, 2017) and programming (e.g. Kjällander et al., 2018) are key activities. Vuorikari and colleagues' (2019) definition of a makerspace is 'any generic place that promotes active participation, knowledge sharing, and collaboration among individuals through open exploration and creative use of tools and technology' (p. 45). Vossoughi et al. (2016) identify three main different conceptualisations of the maker-culture. The first relates to branding and economic enterprises at certified institutions following specific routines (e.g. FabLabs, Techshops). The second relates to democratising access to the tools, skills, and discourses of power previously available only to experts in the makerspace; often referred to as the maker-culture. The third refers to the maker movement as education, especially expanding participation in STEM education through interest driven, multidisciplinary learning environments (Vossoughi et al., 2016). These three conceptualisations can be seen as theoretical typologies and, in practice, they are often mixed and interchanged. This study takes its departure from the third conceptualisation because it investigates how maker activities can be transferred to the classroom. However, we are also interested in the second conceptualisation regarding how maker-culture can be integrated into formal schooling.

Making is based on activities grounded in constructionist learning theory, with learning being production-based and active, rather than passive (Harel & Papert, 1991). Recently (e.g. Vuorikari et al., 2019), it has been argued that makerspaces can help foster skills in the contexts of STEM (Science, Technology, Engineering, and Mathematics) in formal education. Vuorikari et al. (2019) also claim that interdisciplinary projects (as frequently occur in makerspaces) contribute to enhancing students' understanding of STEM concepts. Furthermore, many scholars argue that makerspaces can be used to motivate learners (e.g. Bevan et al., 2015; Maslyck, 2016; Tan, 2019; Vuorikari et al., 2019).

Transferring activities from informal to formal learning environments

In this study, we investigate teachers' self-reflections on their transfer of activities from makerspaces to the classroom. Transfer is a theoretical concept closely connected to learning, which is about the ability to use knowledge or competencies in new contexts. It is defined as the ability to transfer knowledge from one situation or arena, to other situations or arenas (Marton, 2006). Transfer relates to boundary-crossing, i.e. a border needs to be crossed between cultures or contexts (Tuomi-Gröhn & Engeström, 2003), which in this study is represented by makerspaces and formal schooling, and we investigate how the teachers describe and reflect on the transfer process.

It has been claimed that there are general challenges in transferring activities from informal learning environments to formal school settings: activities in schools are not voluntary and are therefore less motivating (e.g. Dierking et al., 2013; Falk, 2001; Tal, 2012). Falk (2005) argued that, through free-choice learning, learners can control their own activities, while school learning is linear and not based on intrinsic curiosity. Hence, bringing students from informal, such as makerspaces, to formal learning environments can be directed with limits in students' ability to freely choose what they want to explore and learn more about (e.g. Tal & Steiner, 2006). Therefore, it has been claimed that moving students from informal to formal learning environments leads to demotivation. However, Stocklmayer et al. (2010) argued that the formal sector should learn from informal settings, as the former has often failed to stimulate students' interest in science, while the latter has succeeded, mainly because of highly innovative presentation.

Halverson and Sheridan (2014) discussed tensions between maker-culture and formal education practices. They asked: 'What is the role of making in schools?' (p. 499). They did not provide an answer but emphasised the risk that institutionalising makerspace activities will stifle creativity and innovation. However, they also argued that the maker movement can have positive effects by focusing on students as producers. It may be a matter of changing ontological and epistemological views, as claimed by Tan (2019):

> …schools adopting makerspaces without changes to their ontological and epistemological views of what constitutes science and technology may not necessarily achieve educative successes, as the complex system of schools requires sympathetic modifications in order that makerspaces can serve its purpose. (p. 77)

Development of knowledge in makerspace activities is often related to Papert's ideology of constructionism, where learning is seen as driven by the learners' own interest and open-ended discovery (Harel & Papert, 1991). However, even though there are several arguments that making activities are suitable for formal education because these can foster development of skills in, for instance, problem-solving, creativity, and digital competences, there are tensions that need to be considered (Vourikari et al., 2019). In formal education, there are intended learning objectives to be achieved, and working intentionally with activities can reduce open-endedness and thus influence the makerspace philosophy, for instance, in terms of personal relevance for the students. Furthermore, there is increasing criticism that activities in makerspaces can become too prescriptive and that students are guided towards re-discovery of unifying principles. Still, the potential of makerspaces in formal education is of interest, and if makerspaces in educational settings are to be developed in successfully, there is a need for teacher training and CPD to facilitate the transfer and implementation of maker activities in schools (Vourikari et al., 2019).

Elements with impact on transfer of makerspace activities

In this paper, we identify four main elements in the literature, which have been discussed as impacting the transfer of makerspace activities: *incoherent learning cultures, identifiable learning goals*, *teachers' self-efficacy,* and *students' motivation*.

First, Vuorikari et al. (2019), Halverson and Sheridan (2014), and Tan (2019) suggest that there might be a lack of coherence in the two learning cultures: makerspaces utilise a freestyle approach to achieve the primary objective of making, whereas learning objectives predominate in school and students rarely decide what they will create. The boundaries set in formal education restrict maker activities, creating tension.

Secondly, there is the question of what is actually learnt at the makerspace. Here, Bevan et al.'s (2015) often-cited quote is apposite: 'It looks like fun, but what are they learning?' Halverson and Sheridan's (2014) discussion of the relationship between classroom learning and makerspace activities (which also implies a lack of coherence between the two cultures) urges a change in how making activities are conceptualised–they are not just a means of improving formal learning.

Thirdly, teachers might be unfamiliar with using high-tech makerspace equipment, such as 3D-printers or laser cutters, and hence lack confidence and self-efficacy (Boeve-de Pauw et al., 2022; De Loof et al., 2019).

Finally, there is the general educational issue of whether the motivational potential of makerspace activities remains when transferred to formal learning settings (Falk, 2005; Tal, 2012).

There might be other challenges to overcome. However, given the gap in the literature, noted by Rouse and Rouse (2022), we specifically wanted to find out how teachers themselves, who had participated in a relevant CPD programme and thereafter introduced makerspace activities to the classroom, reflected on their experience of the transformation process.

Experiences of makerspace activities in formal education

Studies on makerspace activities in formal education often report positive outcomes regarding student motivation (e.g. Vongkulluksn et al., 2018). However, Godhe, Lilja, and Selwyn (2019) found that the critical scrutiny on transferring makerspace activities to formal classroom environments is limited and that reports often present ideal conditions in this respect. Tan (2019) reported similar findings, indicating that activities at the makerspace were entirely student-run. His project was open-ended and authentic, as a collaboration with university staff and industry mentors was encouraged. The project was also of an advanced standard–one student worked, for example, with high-voltage electric circuits. Moreover, Tan reported that the teachers insisted that ‘their students not only learnt *about* science and engineering, but they were actually *doing* it’ (Tan, 2019, p. 84).

However, even though the makerspace activities were taking place at school, they were not part of the formal curriculum; the teachers involved in Tan’s study had a special interest in working in this way. One of them had a background in teaching design and technology, which shares some similarities with maker-culture; another used to teach physics (also a subject with some crossover with makerspace). Furthermore, the makerspace had a designated technician taking care of the high-tech equipment. Older students, familiar with maker-culture, acted as mentors for younger students. The activities in Tan’s study (2019) were not designed to address specific learning goals; rather, they complemented ordinary teaching–indeed, the work was referred to as an ‘after-school club’. Because the activities were not part of the formal curriculum, the learning goals were unclear.

Tan (2019) argued that the context of his study was unique: it was school-based, but it was not part of the curriculum and not all pupils participated–it is therefore questionable if it actually was part of a formal learning context. In contrast, here, we were interested in how makerspace activities could be transferred to a genuine school context, involving all students in a regular class and with teachers conducting the activities as part of the curriculum. Therefore, we designed a case study in which the teachers first participated in a CPD to learn about the maker-culture and simultaneously try to connect it to their school curriculum, and, finally, enact the makerspace activities in their own classroom, after which they could reflect on this experience. Teacher reflections have been shown to be a powerful evaluating tool of teaching practices (Walan et al., 2016).

Method

We used a case study approach, as explained by Yin (2009), providing an example of real people in real situations. Furthermore, we followed a structured and linear process of case design (planned, designed, prepared, collected, and analysed data and, finally, shared the findings) in line with Yin’s description of case studies. Yin also describes that case studies should include at least two sources of evidence. We used reports written during the CPD programme, as well as post-class interviews.

Case study-based research is conducted within a specific social and physical setting (Miles & Huberman, 1994). Here, we investigated how a group of in-service teachers described and reflected on activities they first tried in a makerspace setting and then transferred into their classrooms within a CPD programme. Hence, from a transfer perspective, we are studying what is happening under what conditions and with what effect in two delimited sets of situations (Marton, 2006).

Context of the study

This study took place in Sweden, where the national curricula for compulsory school changed in 2018; adaptations were made to include students’ learning in relation to wider digitalisation (Swedish National Agency for Education, 2018). In Sweden, grades 1–9 are part of compulsory school that follows a common national curriculum. According to the curriculum, students are supposed to develop their problem-solving abilities and use digital tools to translate ideas into practice. Programming is a new content that has been included as a learning objective in the school subjects of technology and mathematics. With this background and with earlier research (e.g. Kjällander et al., 2018) having proved the need for teacher training, invitations were sent via social media to STEM teachers within the Swedish compulsory school system, within a district in central Sweden, to participate in a CPD programme. Eleven of the twelve teachers that participated in the CPD programme accepted the invitation to participate in this study.

In developing the CPD, we followed the design suggestions made by Peterson and Scharber (2018) to ensure that the programme included time for makerspace activities and time for reflection with peers. Peterson and Scharber (2018) suggested that the focus in professional development workshops should be on teaching and learning strategies, on practicing what you preach, exposure to technology equipment, but not on machines, rather on the making. That making can take place without interruption and that time should be allocated for sharing what has been learned. Finally, they argued that participants in professional development workshops should work together, and there is not an all-knowing teacher in the room controlling the activities taking place (like in any maker activity). Further, the teachers were invited to construct knowledge jointly with colleagues during authentic [makerspace] activities, as suggested by Grabman et al. (2019). The teachers in the CPD programme were first introduced to the concept of makerspaces and maker-culture. Here, we introduced the conceptualisation of maker-culture, both as democratising access to the tools, skills, and discourses, and as expanding participation in STEM education through interest-driven, multidisciplinary learning environments (Vossoughi et al., 2016). Thereafter, the teachers were given the opportunity to try activities in a municipal-run makerspace unconnected to schools.

The programme included seven meetings of between three to eight hours, comprising 40 h in total. Activities involved coding and making objects using resources such as *Micro-bits*, *Sketch up,* and 3D-printers for construction (see Table 1 for all activities tested). In all activities, the instructions, except for the first occasion testing the *Scratch* programme, were open in their guidance and not presented in a recipe style. Thus, the teachers were free to choose different solutions and use of equipment when testing the activities. Later, the teachers could choose other makerspace activities they found from internet sites (however, without testing these within the CPD programme) and try them with their students.

Table 1 Overview of makerspace activities tested during the CPD programme

Activity
Scratch. (Programming)
Micro-bits. (Programming)
Solar-powered vehicles. (Designing and building)
Ship design. (Designing and building ships that can carry heavy loads)
Sugar transport. (Designing and building a construction that can transport a package of sugar)
Chain reaction. (Creating a chain reaction with different materials, making the chain as long as possible)
Sketch up. (Digital design programme)

The whole idea of the CPD was to introduce teachers to what a makerspace is, typical makerspace activities, and discuss how these could be implemented in school. Hence, the idea was to present the learning culture in makerspaces and discuss, based on the teachers' experiences after trying activities with their students, how the activities could connect to learning goals in school, as well as from the perspective of development of generic skills, such us creativity and problem-solving. The idea with the CPD was also to develop the teachers' self-efficacy in using makerspace activities and high-tech equipment. Thus, the CPD tried to outline the maker-culture, both in an experience-based manner and descriptively, by allowing teachers to experience the culture during the workshops, but also to learn about the maker-culture and its possible inclusion in formal education, in more traditionally steered and guided professional development activities.

The makerspace staff functioned as mentors and teachers for the CPD-teachers during the activities. The meetings also included pedagogical discussions led by a science education teacher from a university near the makerspace (first author of this article) about transferring makerspace activities to classroom settings. After completing the programme, the teachers chose one of the workshops to implement in their own lessons without any assistance. The teachers needed to accomplish the transfer themselves. Table 2 lists the activities selected and the grades of the classes in which they took place.

Participants

Eleven teachers from five different schools participated in the CPD. Four were teachers at upper primary school (pupils aged 10–12, grades 4–5), with the rest at lower secondary school (pupils aged 13–15, grades 7–9). Nine teachers were female and two were male. All teachers were experienced, with more than ten years in service. They all taught science (biology, chemistry, and physics) and mathematics; nine also taught in the subject technology. The teachers are referred to as teacher (T) 1–11 to maintain anonymity.

Data collection and analysis

Data were collected as individual written reflections after each workshop, and via individual semi-structured interviews conducted at the schools immediately after the teachers had completed a makerspace activity in class, i.e. transferred the maker activity.

Table 2 Makerspace activities that were implemented in class, plus different class grades. Teachers 4 and 5 worked together in their classes to support each other

Teacher number	Activity	Class grade
1	*Scratch*	9
2	*Scratch*	8
3	*Scratch*	8
4, 5	*Scratch*	5 and 6
6	*Micro-bits*	8
7	*Ship design*	4
8	*The pole house*	7
9	*Scratch*	5
10, 11	Did not implement activities in the classroom because of illness	Supposed to be in Grades 8 and 9

The interviews were conducted by the first author, lasting about one hour and were audio-recorded and fully transcribed. (See Appendix 1 for the questions and interview guide).

Data were analysed using thematic inductive coding, as described by Braun and Clarke (2006). First, the first author read the transcripts and the individual reports to get familiar with the material. These initial thoughts were then discussed with the second author. Second, the first author iteratively read the material to identify preliminary codes based on the following procedure: words that were repeatedly used in individual reflections and interviews were marked as keywords (e.g. learning objectives, physics, motivation, engagement, etc.). Third, the first author sorted quotations with keywords into preliminary themes that were constructed. The identified themes were discussed and evaluated between the two authors. A deductive approach, guided by the research question, followed as a fourth step when searching for codes that we could identify as reflections of *possibilities* and *challenges.* The codes reflecting possibilities and challenges relate to words classified as adjectives, adverbs, and interjections reinforcing a statement positively (possibilities), such as *fun, stimulate, well, create*, or negatively (challenges) such as *challenge, problematic*, *need, difficult*. Fifth, the two authors discussed the coding and arranged the finalised themes. Possible disagreements were discussed until consensus was reached. Figure 1 shows the final coding map, including keywords, themes, and how these relate to possibilities and challenges.

In the result section, we code the quotes as written reflections (wr) or oral reflections from the interviews (or). References will thus follow the format wrT1 (written reflection made by teacher 1). The quotations we present are excerpts from teachers that are typical and representative of a theme, however, translated from Swedish into English.

Results

Based on the identified keywords, we could identify seven themes: *Connections to learning objectives in STEM subjects; Motivating and engaging students; Stimulating collaboration; Stimulating creativity; Problem of assessment; Lack of digital competence; Lack of high-tech equipment*. Figure 1 shows the relationship between the coded keywords and the themes. The four themes at the top of Fig. 1 represent themes of possibilities, and the three at the lower part represent challenges.

Here follows an elaborated presentation of the themes.

Connections to learning objectives in STEM subjects

Reflections made during the programme showed teachers identified some makerspace activities that could be related to STEM subjects and their learning objectives. The same possibilities were mentioned after transferring activities to the classroom. Notably, programming activities could be related to learning objectives in mathematics and technology. The teachers were vague about the objectives, but the curriculum for technology in compulsory school (Swedish National Agency for Education, 2018) states that students should learn about technical solutions where electronics are used and how these can be programmed; students are also supposed to create their own constructions, which are controlled and regulated, for example, with the help of programming.

Several activities were found to connect to learning objectives in design processes and knowledge about different materials. Interestingly, the teachers linked makerspace

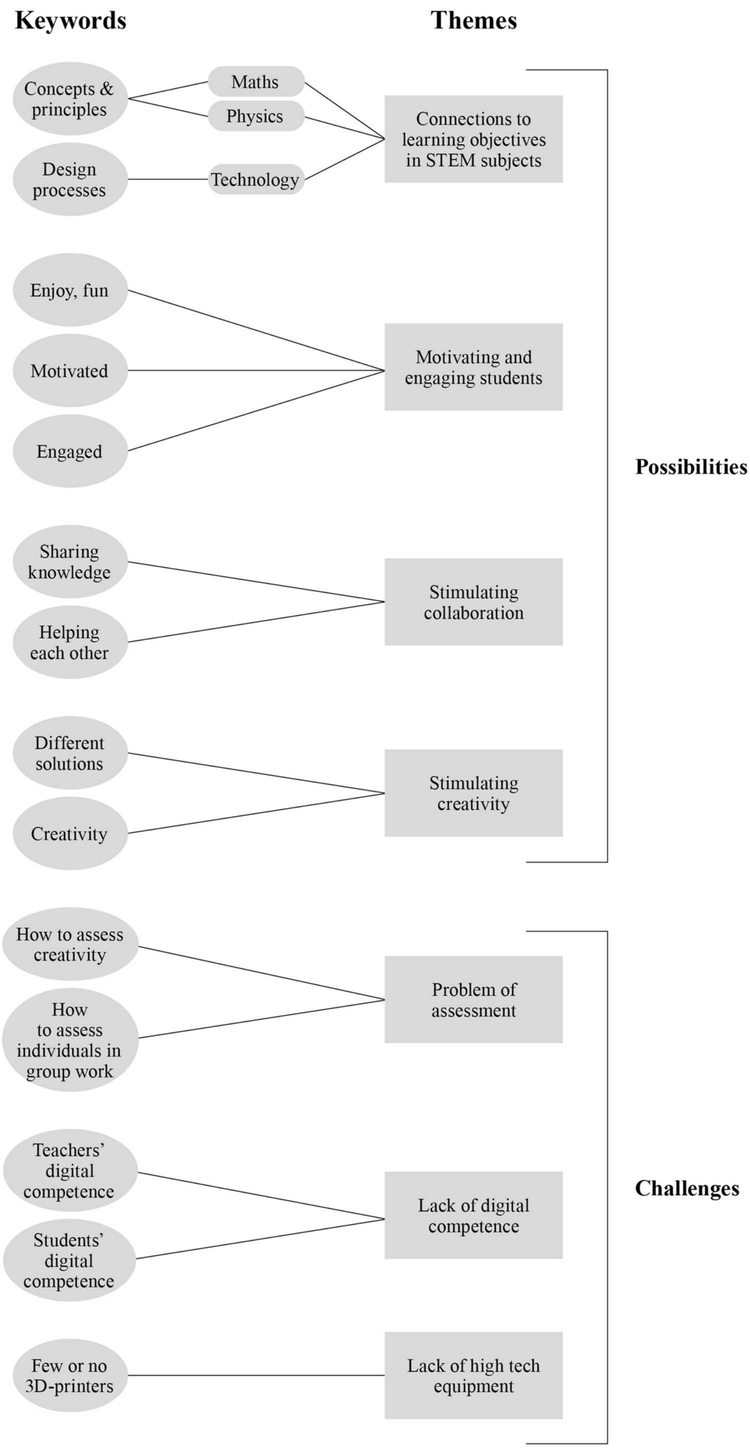

Fig. 1 Final coding map with key words and themes included

activities to the traditional learning of concepts related to mathematics and physics, as exemplified below. Hence, the use of makerspace activities was interpreted by the teachers from a curriculum perspective:

> The programming activities are related to concepts in maths, and the activity with the *solar-cell driven vehicle* can develop knowledge in electronics, mechanics, and friction, concepts that are included in physics. [wrT11]
> *The ship* activity, well float and sink and knowledge about the Archimedes principle, this is part of learning objectives in physics. But knowledge about volume, weight, and area is part of the learning in maths, and this is also part of the makerspace ship activity. I can also find a connection to learning in technology about how to construct, test, and rethink, and knowledge about different materials. [wrT4]
> I believe the students learnt about the concepts of centre of gravity and vertical in another way through this activity [*Pole House*], and this connects to physics. There are many students who used the word centre of gravity, so concepts start to become part of their vocabulary, and they use it correctly too. [orT8]

Motivating and engaging students

Reflections during the programme on motivation and engagement were overwhelmingly positive. After the teachers had conducted the activities in their own classrooms, they remained positive and argued that students had been active during the makerspace activities and seemed to enjoy themselves:

> I think that the activities we did today [*Scratch* and *Solar-driven vehicle*] will stimulate the students and enable them to gain knowledge in a playful and fun way. [wrT3]
> The activity with *Scratch* is quite open. That's fun! It will lead to both engaged and motivated students. [wrT9]
> I was surprised that they [the students] seemed to enjoy the activity with *Scratch* so much. I think it is quite monotonous to programme, but still, maybe because they were programming a game, they found it to be fun. Also, they can see the effects of what they are doing immediately, and that is perhaps stimulating; all of them were engaged during the whole lesson, even if a few of them did not finish. [orT3]

Stimulating collaboration

The teachers reported that makerspace activities could support students' skills in collaborating, whether working in groups or in pairs. In some classes, students already had programming skills, and they helped others, not only the person they were sitting next to:

> Well, we have this student, Oscar [fictive name]; he knows how to programme. He probably does it at home. He notices when there are errors in his classmates' codes, and he helps others. So, I mean that's an example of sharing knowledge. I would say that it's an example of collaboration in a way. [orT2]

I made them work in groups, and it worked really well in all the groups.

> They discussed how to construct the *Pole House* and helped each other to measure. [orT8]

Stimulating creativity

The teachers also argued that makerspace activities could stimulate creativity. There were even occasions when the teachers were surprised because they had not expected that the activities, essentially about programming, could lead to this outcome:

> There are a lot of possibilities to develop creativity in the programming activity [*Scratch*] even though it is quite guided in the beginning. The creativity comes when they will create their own games later on. [wrT7]
> The car [*Solar-driven vehicle*] is based on creativity all the time, and they need to think of what will happen if they test different solutions. [wrT7]
> I noticed that there were some students that already were creative when they programmed. For instance, suddenly, one guy had changed the coding from the instructions, so there was not a cat in the game, but he had changed it into a picture of himself! It is so cool to see what they come up with. [orT1]

The problem of assessment

How to assess students' work in makerspace activities often came up during the CPD as a challenge. Issues about assessment were discussed regarding creativity and collaboration. The challenge was not for the students to develop creativity during makerspace activities, but for the teachers to know how to assess this development. The importance of assessing in the school context was also emphasised, but teachers were confused about what creativity actually is and what assessment criteria to use:

> I believe it can be difficult to assess students' creativity, and also, if they work in groups, who did what? Who was the one being creative? [wrT6]
> It is a challenge to include development of students' creativity skills because it is not included as a learning objective in the STEM subjects, and it is also a problem to assess this. How do you assess creativity? [orT7]
> It is a problem to assess when students work in groups, because you don't know who did what and who came up with the ideas to solve different problems and so on. [orT10]

Lack of digital competence

None of the teachers used digital fabrication with their students; many did not feel competent, for instance, working with *Sketch up*:

> It was difficult to make it work with *Sketch up*. I will need to test it more myself before I try it with my students. [wrT9]

Those who transferred the programming activity with *Scratch* also reflected on their lack of digital competence:

> I feel like a total beginner working with programming; it felt good the first time to follow the guide. It was really challenging for me. [wrT19]
> It was a challenge for me as a teacher to detect errors in the students' programming. I am not good enough at programming yet. [orT9]

Also, the teachers commented on the students' lack of programming competence:

> There were students in my class who had difficulties when we worked with *Scratch*. They are not following the instructions, which is a problem, especially for some students who think that this is easy, and they skip some steps and, of course, then they get stuck. [orT2]
>
> This is the first time with programming for my classes. I tested *Scratch* with another class, and everything worked just great. But, in this class, well, they did not have patience, and they did not find the errors in their programming, and some simply did not search for the errors, they just wanted my help. Still, this was the first time; they need to practise and get into a routine. [orT2]

Lack of high-tech equipment

Lack of competence was not the only reason for failing to include digital fabrication in class: lack of high-tech equipment was also recognised as a challenge:

> We have one 3D-printer at my school. I have tried it for tasks when classes have participated in the First Lego League competition. However, I think it will be problematic having just one printer in makerspace activities, because it takes quite some time to print. [wrT11]
>
> When we did this *Pole House* activity, oh, how I wished that we had a 3D-printer so they could have, for instance, printed furniture for their houses, but we don't. Also, if we had 3D-printers, we would have needed more time. [orT8]

Summarising possibilities and challenges in transferring makerspace activities to classrooms

The teachers found that there were possibilities and challenges in transferring makerspace activities to classrooms. Four of the seven themes we identified focused on possibilities: *connecting to learning objectives in STEM subjects, motivating and engaging the students, stimulating collaboration,* and *stimulating creativity*; three of the themes focused on challenges: *problem of assessment, lack of digital competence* (among teachers and students), and *lack of high-tech equipment*.

There were hardly any differences between the teachers' reflections depending on which activity they tried in their classrooms. The only differences noticed were the connections to the objectives in different STEM subjects. Those who chose *Scratch* referred to knowledge in mathematics and technology. While, for example, the teacher who chose *Ship design* referred to learning in physics and technology. This is not surprising because the activities relate differently to the curricula and syllabi of various subjects.

Discussion

Here, we have reported how teachers' perceptions of the possibilities and challenges in transferring makerspace activities into their classrooms changed after participating in a CPD programme and thereafter implementing activities with their students. The results showed the teachers found possibilities and challenges to overcome if transferring makerspace activities to classrooms on a more permanent basis. The teachers reflected closely upon *learning goals, self-efficacy,* and *students' motivation*, but not directly on the different *learning cultures*. Hence, teachers saw potential links to the learning goals in STEM subjects, and generic goals such as creativity, motivation, and collaboration. The challenges in being able to conduct assessment were recognised, and the self-efficacy problem was acknowledged in the themes of lack of equipment and competence.

Although not expressed explicitly, cultural differences can be inferred in the teachers' uncertainty: by suggesting and discussing traditional conceptual learning within mathematics and physics and traditional assessment practices, they are promoting a cultural shift away from student-centred free-choice learning and making (the hallmark of maker-culture) to teacher-centred content learning (characteristic of formal education). The teachers could not verbalise this conflict between the cultures, but they recognised its consequences (e.g. assessment problems). This is important because if we are to transfer makerspace activities into formal schooling, the profound cultural differences need to be discussed in full, and makerspace-inspired motivation was also seen as a possibility.

Tensions when transferring makerspace activities into formal schooling

Earlier reports (e.g. Davies, 2017; Kjällander et al., 2018) have discussed the potential of makerspace activities for teaching and learning, and indeed some of the same possibilities were touched upon by the teachers in this study. However, it is important to note that there *is* a difference between activities in an informal makerspace and activities taking place in a formal school setting. Maker activities build on constructionism where learning is driven by learners' own interest and open-ended discovery (Harel & Papert, 1991), in contrast to formal education, where there are intended learning objectives to be achieved. For the teachers in this study, taking makerspace activities in school, the connection to learning objectives in the STEM curricula was vital; this is an example of a tension between informal and formal learning that needs to be considered–in a makerspace setting, the formal curricula is irrelevant, and the focus is on creating by free choice (Vuorikari et al., 2019). However, our teachers found a connection to learning objectives to be a necessary prerequisite for transferring makerspace activities into formal schooling. Based on these results, we can see that the teachers missed the opportunity to re-conceptualise their role in relationship to their students. Perhaps this could have been stressed more in the CPD. However, teachers' role as teachers relates to the construct of teacher beliefs. As shown in previous research, these are stable and very difficult to change (Fives & Gill, 2014). Hence, teachers' beliefs might be one major obstacle for implementing maker activities in formal schooling. Therefore, our results indicate that transferring makerspace activities in the way suggested by Tan (2019) might prove to be difficult, in a Swedish context at least. Below follows a discussion of how the identified themes of this study relate to the issue of transfer and how they relate to previous studies.

Even though the students in our study did not have a free choice of what to create, they were all motivated and engaged during the activities. Papavlasopoulou et al. (2018) concluded that most reports about motivation outcomes from makerspace activities are positive; indeed, they were surprised that there were hardly any studies reporting negative results about students' motivation and engagement. The only exception was the study by Chu et al. (2015) who found that frustration and boredom can arise because of usability problems. In our study, positive motivation and engagement were reported. However, it is important to remember that the teachers' reports concern one lesson only; in all classes, the activities were taking place for the first time–the positive results may be a novelty effect.

Likewise, collaboration has been reported as an outcome in some studies about makerspaces (e.g. Bevan et al., 2015; Maslyk, 2016; Vuorikari et al., 2019), which the teachers in our study also reported as a positive effect when transferring makerspace activities into the classroom.

Echoing earlier work (e.g. Bevan et al., 2015; Maslyk, 2016), the teachers in our study claimed that the activities stimulated student creativity – some were even surprised that programming led to creativity. However, the challenges in assessing development of creativity were raised–another example of a tension that arises when makerspace activities are transferred into a formal school environment. Halverson and Sheridan (2014) suggested that institutionalising makerspace activities could hinder creativity; this might be the case when teachers implement assessment practices in makerspace activities. The question arises: how will these teaching practices affect students' creativity when constantly assessed? There is an absence of established measures of these kinds of activities (e.g. Godhe et al., 2019) and outcomes such as development of generic skills like creativity (e.g. Care & Kim, 2018). This warrants future investigation: if makerspace activities are going to be transferred into formal schooling, issues regarding assessment should be addressed.

The remaining themes relate more to technical issues and are perhaps less complicated to address than the aspects discussed above. Digitalisation is still a new phenomenon in Swedish schools and in Belgium (e.g. Boeve-de Pauw et al., 2022; De Loof et al., 2019); our results–showing that teachers have low self-efficacy in using digital tools and a lack of digital skills among students–are not totally unexpected. This challenge has been accentuated, as programming was recently added to the Swedish curriculum. Teachers clearly need support in their use of digital tools: one way forward could be for schools to collaborate with makerspaces: students could visit the space(s), or, alternatively, makerspace staff could go to schools and support teachers and students in situ, as reported by Tan (2019).

Utilising high-tech equipment for digital fabrication was considered a challenge since such equipment are not yet available in all Swedish schools. Hopefully, this will be accomplished in the future, but there are many schools that are financially strapped and buying high-tech equipment is not a priority–a big hurdle if makerspace activities are to be transferred into formal schooling.

Finally, it is important to remember that makerspaces are informal and have a different ethos and role compared to schools: they are voluntary, which lends them a certain culture that will always be difficult to reproduce in a context such as a school. However, some aspects of makerspaces can and should be brought into formal school settings, as shown in this study. Makerspace activities should support learning, but other things can be achieved if we move beyond this aim; students cannot only learn *about* science and engineering, they can also *do* science and engineering, as Tan (2019) argued.

Conclusion

In this study, we considered teachers' reflections on the possibilities and challenges of transferring a makerspace activity to their classrooms. The teachers in this study believed there were more possibilities of transferring makerspace activities to their classrooms than challenges, and they were genuinely positive about transferring maker activities to their schools. Our results show the teachers were practically minded, and they did reflect little on the finer ontological and epistemological points of transferring makerspace activities into formal schooling. In that way, their beliefs in their role as teachers in relation to their pupils were not reconsidered in the CPD, making it difficult to transfer maker activities based on true constructionism, where learning is driven by pupils' own interest and open-ended discovery. Instead, they tried to develop a hybrid form of makerspace activities that unfolded challenges stemming from formal curriculum schooling demands, such as assessment. Hence, from this aspect, we agree with Godhe et al. (2019) that if makerspace activities are about to be transferred to formal education settings, epistemological and pedagogical aspects of makerspace activities as tools for learning must be considered even more.

The more practical challenges identified by the teachers could probably be simply solved through access to high-tech equipment and in-service training: a seemingly straightforward solution, but the issue needs to be recognised throughout the school system as a priority. Currently, this is not happening, at least in Sweden; to convince the government, we need to establish why makerspace activities should be transferred to formal schooling. The teachers in this study shared only vague ideas about this, despite spending 40 h in the CPD programme. Hence, these issues will need to be discussed further within the education profession before transfer of makerspace activities is possible. What are the aims of STEM education that include makerspace activities, and how do we reach those aims? What can be learnt from makerspace activities and how can learning occur? What role should the teacher take in relation to their students and the technology? Should learning take place in separate subjects or within interdisciplinary settings? Our conclusion is that if a transfer is to occur, more efforts will be needed to discuss the main ideas, not only among teachers but also in policymaking and government circles.

Based on our findings, we would also argue that it is difficult 'to eat the cake and have it too', that is, to fully combine maker-culture and the demands of formal schooling, at least without negotiating the role of the teacher. Rather, today, three pragmatic options are available: (i) Adapt maker activities to the formal school organisation, correlating activities to the curriculum and assessing accordingly. In doing so, many elements of the maker-culture will be lost; (ii) Transfer more authentic maker activities as a kind of 'add on' to the curriculum. The maker-culture will remain largely intact, but at the cost of high demands on teachers and increased student disconnectedness from the curriculum; and (iii) Take the students to makerspaces outside school. This would preserve the maker-culture but demand close administrative collaboration between institutions. In sum, transferring some aspects of makerspace activities to the classroom is possible, but the way forward is perhaps not to institutionalise makerspace culture.

Limitations and future research

We used all the data collected when identifying themes. It is possible that a larger study including more participants in the CPD could have generated additional themes. However, methodological studies have shown that 90–95% of themes are identified after 10–12 interviews (Guest et al., 2020), suggesting that saturation is probably reached in the study.

A limitation of the study is that we only investigated the teachers' self-reported reflections on transferring makerspace activities. For future studies, it would be interesting to make direct observations in classrooms and makerspaces.

Another research gap drawn from this study is the need for investigations on how teachers understand their role as teachers when transferring makerspace activities in school, and how this can be re-negotiated to meet the maker-culture.

Appendix 1

Questions for individual reflections after each workshop with activities at the makerspace:

(1) How can you transfer the activities from today to your classroom?
(2) What kind of challenges do you identify?
(3) How could you handle the challenges?
(4) What have you learnt yourself after testing the activities?
(5) What kind of possibilities can you identify in terms of students' development of:

  (a) Creativity?
  (b) Problem solving?
  (c) Collaboration?
  (d) Critical and analytical thinking?
  (e) Learning in STEM subjects?

Questions for semi-structured interviews after implementing makerspace activities in the classroom.

(1) What kind of makerspace activity did you choose to transfer to your classroom?
(2) Why did you choose this activity?
(3) Which class did you work with?
(4) What was most important for you that the students would achieve from this activity?
(5) Was there anything you would like to change in this activity? If so, what and why?
(6) How did it go? What went well? Where there any challenges; if so, what kind of challenges and did you handle them?

Anything else you want to say about the transfer of the makerspace activity to your classroom?

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Declarations

Conflict of Interest The authors declare that they have no conflicts of interest.

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