Research in Science & Technological Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/crst20

Teachers' self-efficacy and role when teaching STEM in high-tech informal learning environments

Jelle Boeve-De Pauw, Haydée De Loof, Susanne Walan, Niklas Gericke & Peter Van Petegem

RESEARCH IN SCIENCE & TECHNOLOGICAL EDUCATION
https://doi.org/10.1080/02635143.2022.2089873

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Teachers' self-efficacy and role when teaching STEM in high-tech informal learning environments

Jelle Boeve-De Pauw[a,b], Haydée De Loof[a*], Susanne Walan[c*], Niklas Gericke[c] and Peter Van Petegem[a]

[a]Department of Training and Education Sciences, Faculty of Social Sciences Research unit Edubron, University of Antwerp, Antwerp, Belgium; [b]Utrecht University, Faculty of Science, Freudenthal Institute, CC Utrecht, The Netherlands; [c]Faculty of Health, Science and Technology, Karlstad University, the Centre of Science, Mathematics and Engineering Education Research, Karlstad, Sweden

ABSTRACT

Background: Informal learning environments (ILEs) like Fablabs and Makerspaces have potential to facilitate development of STEM skills. However, these environments might be difficult for teachers to adopt in their teaching because of teaching approaches grounded in constructionism where the role of the teacher changes from a transmissive instructor to an active co-creator, and using high-tech equipment not normally found in schools.

Purpose: The aim is to investigate teachers' self-efficacy and perceived role when teaching STEM in Fablabs and Makerspaces. This is investigated related to teaching in ILEs and using high-tech equipment. The study was conducted in two countries/regions, Flanders (Belgium) and Sweden We also compare differences between teachers depending on nationality, gender, and years of teaching experience.

Sample: A total of 347 secondary school teachers completed an online survey. Quantitative analyses was used for all questions in the survey, except one open-ended question, which was analysed through inductive thematic coding.

Results: The teachers reported moderate self-efficacy for teaching in ILEs , and low self-efficacy for using high-tech equipment. Some teachers described themselves as having active roles as a coach or as co-learner during visits with their students. Others saw themselves as having a passive role. Many teachers did not know what kind of role to take. The teachers who perceived an active role as a teacher in high-tech ILEsreported higher self-efficacy to teach in these environments than other teachers.

KEYWORDS
Informal learning environments secondary teachers; self-efficacy; STEM; teacher role; technology use

CONTACT Susanne Walan susanne.walan@kau.se Department of Training and Education Sciences, Faculty of Social Sciences, Research Unit Edubron, University of Antwerp, Prinsstraat 13, 2000 Antwerp, Belgium; Utrecht University, Faculty of Science, Freudenthal Institute, Princetonplein 5, 3584 CC Utrecht, The Netherlands; Karlstad University, The Centre of Science, Mathematics and Engineering Education Research, Universitetsgatan 2, 651 88 Karlstad, Sweden

*These authors contributed equally to this work as first authors

Authors notes : The first three authors designed the study and share the contribution equally and should all be considered as the first authors. Here, they are listed in alphabetical order based on their family names. Together with the fourth author, they developed the questionnaire that was used and discussed the methods for analysis. The first author in the list conducted the statistical analysis, and the second and third authors in the list conducted the analysis of the open-ended question. The fourth and the fifth authors had an overall responsibility of the study.

Supplemental data for this article can be accessed at https://doi.org/10.1080/02635143.2022.2089873

Conclusions: This study shows that a constructionist approach to teaching is important if teachers are to develop self-efficacy to teach in high-techILEs. Thus, developing teacher practices in line with constructionism in relation to teaching in high-techILEsis imperative, in teacher education. The results also highlight that staff in Fablabs and Makerspaces are important for handling high-tech equipment. Hence, collaboration between staff in ILEs and teachers is of importance.

Introduction

Environments focusing on student-centred and problem-based active learning with open access to high-tech manufacturing equipment are interchangeably referred to as Fablabs, Makerspaces, and Hackerspaces (among others). Such environments are established in several countries, and being discovered by teachers for its potential to teach and learn STEM (Science Technology Engineering Mathematics) (Kurti, Kurti, and Fleming 2014). In these environments, skills that are considered as important for the future, so called 21st century skills are being developed when people engage in making activities (Maslyk 2016). Skills include: creativity, problem-solving, communication and collaboration (ibid).

Fablabs and Makerspaces can be characterised as communal open ateliers where citizens share access to tools that allow them to (co)create products and services, and as spaces where they can come together to invent, think, explore, and discover. A typical feature of these spaces is the use of high-tech tools and materials such as 3D printers, laser cutters, and similar equipment. Even though Fablabs and Makerspaces are found both in informal learning environments (ILEs) and in formal education, the most common setting so far is as an ILE (e.g. Peppler, Halverson, and Kafai 2016a,b). Here, we focus on Fablabs and Makerspaces as ILEs and on teachers' self-efficacy and role when teaching their students in these ILEs. The teachers normally teach in formal education characterized of a structured education system, comprising curriculum and assessment of learners' acquired learning or competences. However, in ILEs teaching and learning is often unplanned and unstructured (European Council 2022). These differences between formal and informal learning environments could pose an obstacle for teachers to teach in ILEs because they might lack self-efficacy and understanding what role to take in ILEs and how to use the high-tech equipment normally not present in school, which is the problems investigated in the current study. Still, teaching in ILEs is important in formal STEM education as it has been shown to improve important learning goals such as creativity and problem-solving (Maslyk 2016). As a consequence, bringing students to ILEs to teach STEM has long been recognized as important complement to formal education (Rennie 2014).

Although the impact of ILEs on students has been investigated (e.g. Blikstein 2013; National Research Council 2009; Walan and Gericke 2019), there seems to be few investigations into the extent to which teachers feel prepared to teach STEM and to facilitate the learning of STEM competencies when bringing their students to high-tech ILEs like Fablabs and Makerspaces.

Hence, in this study we pose three connected research questions. Two of them explicitly address the lack of knowledge about teachers' self-efficacy, with respect to teaching in ILEs (Al Bataineh and Anderson 2015; Morag and Tal 2012). Furthermore, we also address the changed role teachers need to adapt to when visiting ILEs with their students if it is to connect to the theoretical underpinnings of constructionism that is related to high-tech ILEs (e.g. Freeman et al. 2017).

(1) How are teachers' self-efficacy in: (a) using informal learning environments in their teaching in general versus specific in Fablabs/Makerspaces (b) using technological equipment?
(2) How do teachers from various countries (Belgium and Sweden), of different gender, and having different levels of teaching experience, differ with regarding these two self-efficacy measures?
(3) How do teachers describe their own role when visiting informal learning environments such as Fablabs and Makerspaces with their students?

Background

First, we define what is meant by high-tech ILEs like Fablabs and Makerspaces. We also outline studies on teachers' readiness to teach their students in these environments as situated in ILE contexts. Thereafter, we outline the theoretical background of self-efficacy as well as studies on teachers' self-efficacy and perceived role of teaching in high-tech ILEs.

High-tech learning environments such as fablabs and makerspaces

Fablabs (short for Fabrication Laboratories) are spaces where people meet, exchange ideas, and collaborate with the goal of designing and digitally manufacturing custom built objects. Such environments were first introduced at Massachusetts Institute of Technology in 2001 (Gershenfeld 2005). All Fablabs have at their core the same hardware and software capabilities, allowing for people and projects to be easily distributed across them. They are commonly set up in the context of an institution, such as in a university, a foundation, or a company. Fablabs are supported by a global Fablab association, responsible for dissemination of the Fablab concept and promotion of collaboration among Fablabs (Rosa et al. 2017). Besides access to specific sets of equipment such as 3D printers, laser cutters, CNC mills, etcetera, the activities have a constructionist approach to teaching and learning (Martinez and Stager 2013).

A constructionist approach means that learning is production-based and active, rather than passive (Harel and Papert 1991). Sometimes, it is simplified as being a matter of 'learning-by-making', but Harel and Papert (1991) argued that it is much more multifaceted than that. It includes student-centred, discovery and project-based learning, where students make connections between different ideas and areas of knowledge. According to constructionism, maker activities are also interest-driven (e.g. Dougherty 2013). Constructionism is related to constructivist learning theory in the sense of defining learning as building knowledge structures, irrespective of circumstances of learning. However, constructionism is an extension of constructivist learning theory (Sheridan et al. 2014), but in constructionism focus is on the learning that occurs when people are constructing physical or digital artefacts (e.g. Papert 1993; Tan 2019). We do not argue that constructionism is not occurring in formal education in classrooms, but this learning theory is strongly connected to learning in high tech ILEs and is therefore of importance for this study. Moreover, Resnick and Rosenbaum (2013) claim that constructionism is out of favour in many of the formal education systems and that teaching in ILEs therefore are important to further stimulate constructionist learning.

Makerspaces are similar to Fablabs; however, such spaces emerged from groups of independent individuals who wanted to share their making and spaces with other enterprises who value joint engagement and access to a range of tools and materials including digital equipment (Peppler, Halverson, and Kafai 2016a). Makerspace refers to any generic space that promotes active participation, knowledge sharing, and collaboration among individuals through open exploration and creative use of tools and technology. Originally, it was presented in MAKE Magazine in the context of creating tinkering-spaces for children (Cavalcanti 2013). Tinkering is defined as an experimented, iterative style with the tinkerer exploring new paths and possibilities, trying out ideas, making adjustments and refinements, namely a style of making physical or digital artefacts (Resnick and Rosenbaum 2013). In Makerspaces, digital fabrication and programming are key activities (e.g. Davies 2017; Kjällander et al. 2018), and high-tech equipment that was previously found only in larger organisations is common (e.g. Dougherty 2013; Halverson and Sheridan 2014). Thus, Fablabs and Makerspaces are similar ILEs when it comes to learning approaches and high-tech equipment.

As mentioned, Fablabs and Makerspaces are most often considered as ILEs (Peppler, Halverson, and Kafai 2016b), even though these kinds of environments are being set up in schools and incorporated into the curricula in some countries (Vuorikari, Ferrari, and Punie 2019). Often, it is argued in the literature that in these ILEs, a different culture, a maker culture, is created that is quite different from formal schooling. Here, student-centred, discovery, and project-based learning that is interest driven comes at fore, which is quite different from curriculum, teacher-centred, and assessment-driven formal STEM education (Dougherty 2013). Moreover, the maker culture is multidisciplinary, including aspects of several school subjects such as art, physics and mathematics, which is different from the discipline based schooling. However, the inclusion of STEM knowledge in maker culture is pointed out as a possible bridge overriding the differences between the maker culture and formal schooling (Vossoughi, Hooper, and Escudé 2016).

Regardless of whether maker activities take place in a Fablab or a Makerspace, it has been argued that making in these environments can assist in fostering skills in the contexts of STEM (Vuorikari, Ferrari, and Punie 2019). Furthermore, many scholars argue that Makerspaces can be used to motivate learners (e.g. Bevan et al. 2015; Tan 2019; Vuorikari, Ferrari, and Punie 2019). Moreover, research have shown that activities in Fablabs and Makerspaces can contribute to makers' development of skills that are important for the future, such as creativity, collaboration, critical thinking, problem-solving, etcetera (e.g. Bevan et al. 2015; Peppler, Halverson, and Kafai 2016b; Vuorikari, Ferrari, and Punie 2019). Addition, Ryan et al. (2016) argue that maker-centred learning also promotes development of a sense of personal agency and self-efficacy, capacities that are related to human development (Ryan et al., 2016). Moreover, Andrews, Borrego, and Boklage (2021) found that students who visited a Makerspace showed increased self-efficacy in design and innovation, technology, and in belonging to the Makerspace and the community. Hence, there are several positive reports on benefits to students from participating in these kinds of environments. On the other hand, studies reporting on teachers' self-efficacy or role when teaching in high-tech ILEs, such as Fablabs and Makerspaces, seem to be few. Hence, this is the research gap this study aims to fill.

Teachers' self-efficacy when teaching STEM in informal learning environments

Before reviewing the few findings that have been reported relating to teachers' self-efficacy teaching STEM in ILEs in general, and more specifically in high-tech ILEs, we return to the definition of self-efficacy as described in literature, since it is a central theoretical concept in our study.

Self-efficacy has been defined by Bandura (1993) as a person's belief in their ability to succeed in a particular task in a particular situation. The construct thus relates to perceived beliefs about a person's capabilities rather than their actual capabilities. According to Bandura (1993), self-efficacy affects cognitive processes: the greater the self-efficacy, the higher the goals that are set and the greater the commitment to performing specific tasks. Perceived self-efficacy affects how people deal with failures and their level of patience when encountering difficulties. When specifically discussing teachers' self-efficacy, the concept relates to teachers' beliefs in their ability to motivate and stimulate learning. When teachers' self-efficacy is low, this will have a negative effect on students' learning (e.g. Guo et al. 2012).

Pajares (1992) suggested that a person is likely to pursue activities and situations in which they feel competent, and to avoid situations in which they doubt their own capability. Similarly, researchers (e.g. Guskey 1988; Stein and Wang 1988; Woolfolk Hoy and Davis 2006) have argued that teachers with high self-efficacy are more open to new ideas and are willing to test new methods to better meet their students' needs. Recent studies support the importance of studying teacher self-efficacy as a key concept to understanding why and how, across diverse situations, teachers have different impacts on student learning and achievement of educational goals (e.g. Künsting, Neuber, and Lipowsky 2016).

From a specific perspective on teachers' self-efficacy teaching in ILEs, there are few studies available. There are studies, however, investigating teachers' lack of skills in teaching within ILEs, often concluding that teachers need help to develop pedagogies for teaching and learning in ILEs (e.g. Griffin 2012; Tal, Bamberger, and Morag 2005). It is reported that teachers lack skills to manage visits to ILEs, often they often relying on educators in the ILEs to scaffold students' learning during the visit.

In studies on teachers' self-efficacy to teach in high-tech ILEs, we find that in the context of STEM teaching, it has been claimed that teachers are uncertain about the meaning of the T in STEM (El-Deghaidy and Mansour 2015); hence, technology presents a major challenge for teachers. For example, Hasse (2017) argued that teachers lack the technological literacy needed to implement new educational technologies in their classrooms. Hasse (2017) refers to technological literacy, as defined by International Technology Education Association (International Technology Education Association 2000/2007), which is the ability to use, manage, assess and understand technology. However, she argues that technological literacy should benefit from including other aspects as well, such as how technology change relations, identities and power structures. Here, we do not go that far; instead we focus on teachers' self-efficacy to use high- tech equipment found in Fablabs/Makerspaces, thus the management part described in International Technology Education Association (2000/2007). Self-efficacy has been identified as a factor influencing teachers' technology integration in teaching (e.g. Ertmer and Ottenbreit-Leftwich 2010). If teachers have low self-efficacy in using technological equipment in their classrooms it can be expected that this could be problematic when bringing their students to high-tech ILEs (Walan 2020).

It is not surprising that teachers lack professional knowledge related to digital technology and design thinking, since this is not part of their basic teacher training (Eriksson et al. 2018). Similary, Wardrip and Brahms (2016) found that teachers requested professional development in how to handle tools, materials, and to create making projects. However, Song (2018) was aware of this situation and conducted an action-research study involving pre-service teachers to improve their self-efficacy in using technology. The pre-service teachers tested different kinds of technology in a Makerspace, and it was found that they, for instance, gained self-efficacy in using 3D printers and Tinkercad software. Hence, it is not conclusively found that all teachers lack self-efficacy in integrating high-tech ILEs into their formal STEM teaching. Therefore, investigating teachers' readiness to teach in ILEs using high tech equipment is important.

Background variables influencing teachers' Self-efficacy when teaching STEM in high-tech informal learning environments

As this study focuses on high-tech ILEs, which are new to most people (Peppler, Halverson, and Kafai 2016a), trends in teachers' self-efficacy may differ from those of other ILE types. Given the context's novelty, we also investigate the effects of *gender* and the *teacher's experience* with high-tech equipment. Indeed, studies have shown that both these factors can affect self-efficacy (e.g. Al Bataineh and Anderson 2015; Woods et al. 2008), however, the results of these earlier studies are not entirely consistent.

From the *gender* perspective, Al Bataineh and Anderson (2015) found that female teachers had higher self-efficacy in using new technologies than did male teachers. Conversely, Woods et al. (2008) found that levels of self-assessed ability using technology were significantly higher among male physics education teachers than among their female counterparts. Generally, i.e. not specifically related to teachers' self-efficacy, studies have noted that Makerspace activities are often seen as male pursuits (e.g. Eriksson et al. 2018). It may therefore be assumed that this notion of maker culture as male dominated can affect females' self-efficacy as makers and perhaps also as teachers in such an ILE. Consequently, it is important to investigate possible gender differences relating to self-efficacy when teaching in these environments and using high-tech material. If gender differences are empirically found, efforts needs to be made to change the notion of maker activities as a male culture, if we want also female teachers to teach STEM in Fablabs and Makerspaces.

From the perspective of *teaching experience*, studies have shown that teachers' evaluations of their ability in using technology are contradictory. Some studies report no significant differences in the use of technology in teaching between teachers with different levels of teaching experience (Woods et al. 2008). Other studies indicate that length of teaching experience has a significant effect and that younger teachers with less teaching experience are more likely to use technology (Al Bataineh and Anderson 2015). Considering the use of equipment such as 3D printers, laser cutters, CNC mills and software in Fablabs/Makerspace, it might be likely that these teachers, might have encountered such equipment in their everyday life or even teacher training, making it of interest to investigate possible differences in self-efficacy to teach in these environments and to use high-tech material.

These results raise questions regarding the existence of a relationship between gender and self-efficacy in using technology in teaching, the influence of age/teaching experience, and the possibility that older teachers might be expected to be more conservative and less well acquainted with new technologies. In short, when studying teacher self-efficacy, gender and teaching experience can be important mediating factors to understand and explain differences among teachers.

Teachers' role when teaching STEM in high-tech informal learning environments

As mentioned, constructionism has been suggested to be the theoretical base for high-tech ILEs such as Fablabs and Makerspaces (e.g. Harel and Papert 1991). In constructionism learning is seen as driven by learners' own interest and open-ended discovery (ibid.) in contrast to formal education, where there are intended learning objectives to achieve. Because of these theoretical underpinnings in constructionism, the teachers' role is suggested to change to an active coach and co-creator, rather than a passive observer and controller (e.g. Freeman et al. 2017).

Intriguingly, in STEM research, little attention has been directed to the role of the teacher in facilitating students' learning in Makerspaces (Kajamaa, Kumpulainen, and Olkinuora 2020). However, researchers have argued that there are great challenges for teachers when they are supposed to teach in Fablabs/Makerspaces because their identities and roles are changed (e.g. Petrich, Wilkinson, and Bevan 2013). The teachers are being repositioned from being the leader in the classroom to becoming a 'guide at the side or, peer at the rear' (Godhe, Lilja, and Selwyn 2019). Some argue that teachers totally rely on educators in the ILE to take the role of scaffolding learning (Tal, Bamberger, and Morag 2005).

Campos, Soster, and Blikstein (2019) concluded that there are several tensions to consider in the meeting between schools and Fablabs/Makerspaces, one of theme being the teacher identity versus the tinker identity. (We understand a tinker in their study, as being equal to a facilitator in the Makerspace). Campos et al. noticed that teachers often mentioned the tinkers as the one being responsible for technology, while teachers have the role of being in command and control. Still, the question of how teachers adopt these new roles in high-tech ILEs is under-explored and will be addressed in this study, linked to their self-efficacy to teach and use high-tech equipment.

Research context

This study was part of a European project designed to identify the competencies that teachers need to teach STEM in high-tech ILEs, such as Fablabs and Makerspaces. The project also aimed to determine how teachers can identify priorities in their own professional development to better support students' learning of STEM competences in the context of high-tech ILEs. The project was run by a consortium, with participants from six countries; the current study was conducted in two of these partner countries, namely Belgium (Flanders) and Sweden. High tech learning equipment such as CNC mills or laser cutters are not common in lower secondary school settings (students aged 13–15) in Sweden or Flanders. Therefore, it is important to investigate the teachers' readiness to teach in ILEs were such equipment and learning spaces are available. Both countries have recently implemented curriculum changes calling for teachers to use high-tech digital learning tools and are thus interesting cases for investigating teachers' self-efficacy to teach in high-tech learning environments. These recent curriculum changes are summarised below.

In Sweden, STEM has traditionally been divided across different subject areas (physics, chemistry, biology, and mathematics). The Swedish national curricula were updated in 2018 to adapt to the development of digitalisation. The underlying principle was that education should help children and students to develop an understanding of how digitalisation affects the individual and society. Students' ability to use and understand digital systems and services should be developed (Skolverket 2018). Besides the curriculum changes, Fablabs and Makerspaces are emerging in virtually all technical museums as well as in science centres and libraries, and the maker-culture is also taking hold in schools (Vinnova 2018).

In Flanders (the Dutch-speaking region of Belgium), STEM has long been part of the curriculum (Knipprath et al. 2018) and traditionally been taught across different subjects (physics, chemistry, biology, and mathematics). The new curriculum introduced in 2019 states that an integrated approach should be prioritized to teaching STEM during the first two years of secondary education (Department of Education 2019). This shift also included a reorientation of STEM education, from being primarily content-based to more competence-based. This has created a significant challenge for science teachers and many of them see a potential in collaborating with one of the many Fablabs or Makerspaces that have been installed in Flanders over the last decade. While these spaces were not connected to education when first established, they are becoming increasingly open to collaboration with schools. Some have even been set up specifically to serve schools' STEM education needs.

Methods

We collected survey data from secondary school teachers in two countries (Sweden and the region of Flanders in Belgium). Statistical analyses were used to measure outcomes of the teachers' self-efficacy from the aspects mentioned, and inductive thematic coding analysis was used to assess the results of the open-ended question. Next, more details are presented about the participants and the procedures.

Participants

The study's participants comprised 347 secondary school teachers (70% from Sweden, and 30% from Flanders in Belgium; 46% male and 54% female) who volunteered to participate. Teachers were recruited during teacher educational conferences and professional development courses, and via professional teachers and Fablab networks. The participants had different lengths of teaching experience (25% <10 years, 75% >10 years), and all of them taught at least one STEM subject in their school. Table 1 summarises the characteristics of the samples.

Procedure and instruments

An online questionnaire was developed to investigate the research questions. The survey instrument asked teachers about their self-efficacy in teaching in ILEs in general, and in specific ILEs, e.g. Fablabs and Makerspaces. The reason for this is that the literature (see background) acknowledge that teachers to teach in Fablabs/Makerspaces need to overcome difficulties that are general to all ILEs, as well as difficulties relating specifically to high tech learning environments. Therefore, we constructed items that reflects teachers' self-efficacy considering teaching generally in ILEs and specifically in Fablabs/Makerspaces. Furthermore, we asked teachers about their self-efficacy in using high-tech equipment. The survey instrument also included one open-ended question about teachers' perceived role teaching in high-tech ILEs. The items in the questionnaire can be found in Appendix I.

The questionnaire was developed by the three first authors as an iterative process and thereafter discussed with the fourth author until a consensus was reached about the final version. The first section comprised items capturing information about the respondents' gender, years of experience as a teacher, and subjects taught. The second section comprised items about teachers' *self-efficacy* in using high-tech equipment. The third section covered *self-efficacy* in teaching in ILEs, in general, and in Fablabs/Makerspaces specifically. These two self-efficacy scales were constructed based on the guidelines of Cohen, Manion, and Morrison (2011, p. 402–403) and the instrument development process described by Gentry et al. (2014). Participants were asked to self-assess their self-efficacy on a 4-point Likert scale to avoid middle category endorsement (Kulas and Stachowski 2013). The final part of included the following open-ended question about the *teachers' perceived role* in high-tech ILEs: 'How do you perceive your own role in the context of a Fablab/Makerspace?' The respondents were invited to describe in their own words how they perceive their role, for example, by giving examples of what they would

Table 1. Characteristics of the Swedish and Flemish samples.

	Sweden		Flanders		Total	
Subject	n	M:F*	n	M:F*	n	M:F*
Biology	102	0.42	28	1.15	130	0,53
Chemistry	104	0.42	18	1.25	122	0,51
Physics	124	0.63	34	1.43	158	0,76
Natural Sciences	129	0.47	18	2.60	147	0,59
Technology	205	0.66	39	2.55	244	0,81
Engineering	2	**	27	2.86	29	3,14
Mathematics	196	0.55	30	0.58	226	0,65
Total***	242	0.70	105	1.38	347	0,86

* calculated as the M to F ratio (number of males divided by number of females)
** in the Swedish sample there were no female engineering teacher
*** because teachers could indicate multiple subjects, the total is not equal to the sum of the subjects

do in such an environment, or by highlighting how they would support the students or collaborate with staff at the ILE. We identified three distinct roles based on the responses to the open question. Each teacher was categorised into one of these roles based on his or her response, and a dummy variable was created for each role, to be able to compare teachers' self-efficacy measures based on that role.

Data analyses

First, to validate the instrument, we conducted an exploratory factor analysis (Principal axis factoring with oblique rotation); using all 13 items listed in the appendix revealed a solution with two factors having an eigenvalue above 1 (6.569 and 2.398, respectively) that together explain 68.98% of the variance. The first factor included all items (4) relating to self-efficacy to use technology, and the second one included all items (9) relating to self-efficacy to teach in ILEs. Reliability was tested through the calculation of Cronbach's alpha values as an estimation of the internal consistency of the scales. The alpha value for self-efficacy in teaching in ILEs was calculated as 0.90 and 0.88 for self-efficacy in using technological equipment. These alpha values are well above the cut-off of 0.65 and we can therefore assume the measure to be reliable. Based on these findings and the previously mentioned Cronbach alpha values, we can assume that our instrument presents content and construct validity as well as reliability of our measures (Taherdoost 2016).

Second, we applied descriptive statistics to study the participating teachers' self-efficacy to teach in ILEs (research question 1a) and to use technology (research question 1b). SPSS v25 (Statistical Package for the Social Sciences) was used for the quantitative analyses. We used Pearson's correlations to estimate associations between the two self-efficacy measures (teaching in ILEs and technology use). Next, analyses of variance (ANOVA) and regression analyses were used to explore potential differences between respondents based on their nationality-, gender-, and teaching experience, for both self-efficacy measures (research question 2).

The responses to the open-ended item on the teachers' perceived role in an ILE (research question 3) were analysed with inductive thematic content analysis, as described by Braun and Clarke (2006). Iterative reading and independent coding conducted by two of the authors revealed three distinct categories. The teachers were coded as having one self-identified role each. Examples of responses to the three categories will be presented in the results section. An excel sheet was used in which excerpts from the open-ended responses in the questionnaire were pasted and coded. Only a few responses required discussion to reach a consensus. The interrater reliability, based on the correlation coefficients for absolute agreement, was excellent (IRR = 0.99); after discussion, a consensus was reached regarding all answers. Analysis of variance (ANOVA) and regression analysis were then performed to explore the relationship between the different types of roles and teachers' reported self-efficacy regarding ILEs and technology use.

Results

Teachers' self-efficacy

The mean values and standard deviations of the scores regarding teachers' self-efficacy to teach in ILE and self-efficacy to use technology, are presented in Table 2. Knowing that the teachers responded to a 4-point Likert scale with (thus, we switch in interpretation between positive and negative at the cut-off values of 2.5) these results indicates that teachers have moderate self-efficacy in teaching in ILEs (including high- technological ILEs, such as Fablabs and Makerspaces) but low self-efficacy in using technological equipment. Teachers' self-efficacy to teach in ILEs was related to their self-efficacy to use technology ($r = .37$, $p < 0.01$). The Cronbach's α internal consistency estimates show an acceptable range above 0.65 (Cohen, Manion, and Morrison 2011), see Table 2.

Differences between teachers' self-efficacy

The overall explained variance of the model was low $R^2 = .04$, indicating that other factors than those included in this study contribute to understanding and explaining differences among teachers in their self-efficacy to teach in ILEs and to use technological equipment. No main effects were found regarding teacher characteristics (i.e. country (F (1, 290) = .07, p = .792), gender (F (1, 290) = 1.03, p = 312), and teaching experience (F (1, 290) = .42, p = .515)) on self-efficacy to teach in ILEs. Table 3 shows the standardised beta coefficients of the main effects and interaction effects. Dummy coding was used, with the last category being a reference category in each case. Non-reference categories are specified in parentheses in the table. A significant interaction effect was found between country and gender. In Flanders, but not in Sweden, men reported higher self-efficacy compared to women.

Conversely, for self-efficacy in technology use, main effects were found for country (F (1, 306) = 29.76, $p < .05$) and gender (F (1, 306) = 21.76, $p < .05$). An interaction effect was also found between country and gender (F (1, 306) = 10.31, $p < .05$). Table 4 presents the standardised beta coefficients for all the main effects and the interaction effects. As shown in Table 3, the last category served as a reference category and non-reference categories are specified in parentheses. Male teachers reported higher self-efficacy to use technological equipment than female teachers, and this difference was more pronounced among teachers in Flanders than among those in Sweden.

Table 2. Means, standard deviations and internal consistency for the self-efficacy scales relating to using informal learning environments and technological equipment. Scale ranged between a minimum of 1 and a maximum of 4.

	Self-efficacy in teaching in informal learning environments	Self-efficacy in using technological equipment
M	3.02	1.96
SD	.60	.87
n° of items	9	4

Table 3. Estimates of the effects of country, gender, and teaching experience on self-efficacy in using informal learning environments.

	β	SE	t	Sig.
Intercept	.01	.10	.10	.917
Main effects				
Country [Flanders]	−.09	.21	−.43	.668
Gender [male]	−.19	.16	−1.20	.231
Teaching Experience [<10 years]	−.12	.22	−.55	.586
Two-way interactions				
Country × Gender	.73	.30	2.46	.015
Country × Teaching Experience	.09	.44	.20	.845
Gender × Teaching Experience	.51	.34	1.47	.144
Three-way interaction				
Country × Gender × Teaching Experience	−1.104	.60	−1.85	.065

Note. Non-reference categories are specified in parentheses.

Table 4. Estimates of the effects of country, gender, and teaching experience on self-efficacy in using technological equipment.

	β	SE	t	Sig.
Intercept	−.35	.09	−3.95	.000
Main effects				
Country [Flanders]	.25	.19	1.36	.175
Gender [male]	.27	.14	2.01	.046
Teaching Experience [<10 years]	.08	.18	.44	.661
Two-way interactions				
Country × Gender	1.10	.26	4.22	.000
Country × Teaching Experience	.05	.35	.13	.896
Gender × Teaching Experience	−.18	.29	−.62	.534
Three-way interaction				
Country × Gender × Teaching Experience	−.60	.49	−1.22	.223

Note. Non-reference categories are specified in parentheses.

Teachers' roles in high-tech informal learning environments

Based on the teachers' own descriptions of their role (provided as answers to an open-ended question in the survey), we identified three different categories of responses. The teachers either describe an active co-creator role, a passive observer role, or they do not know what their role is when visiting ILEs, with their students. The active role was characterised by two types of 'active' behaviour. First, active teachers expressed that they wanted to play a supporting role in which they guide and coach the students during their time in the informal learning environment. A second active role is that of the 'teacher as learner'. In these cases, teachers expressed that they wanted to be part of the learning process themselves, and that they saw visits to ILEs as opportunities to participate in learning together with their students.

Teachers reporting a passive role mainly wanted to stay in the background as observers or saw their role as being solely disciplinary, i.e. contributing with knowledge on STEM. A third group of teachers indicated that they did not know their role. Sometimes they indicated that this was due to never having visited a Fablab or Makerspace, or being unfamiliar with the concept of an ILE. An overview of the roles adopted by the teachers, the numbers of teachers adopting each role, and representative answers to the open-ended question for each role are presented in Table 5. Of the 347 participants, 198 answered the open-ended question.

For those teachers for whom were able to attribute a role (198 of the 347 teachers), the perceived role in ILEs, was linked to the reported degree of self-efficacy in using such ILEs ($F (3, 179) = 4.34, p < .05$). The effect of perceived role remained after controlling for country, gender, and teaching experience, showing that there is a main effect of teachers' perceived role in their self-efficacy in using ILEs. Teachers who perceived their role being active in the ILEs, especially focused on being part of the students' learning process, reported higher self-efficacy in using the ILEs. A similar but somewhat smaller impact was observed for an active supportive role. Table 6 shows the standardised beta coefficients resulting from a linear regression analysis, for the different roles, with the unknown role as a reference category.

Similar results were found regarding the relationship between perceived roles in ILEs and self-efficacy to use technological equipment. Teachers adopting different roles differed in their reported self-efficacy to use technological equipment ($F (3, 175) = 18.50, p < .05$), and this effect remained after controlling for country, gender, and teaching experience. Teachers who perceived their role as being active reported higher levels of self-efficacy to use technological equipment than teachers who did not know their role. Table 7 presents the standardised beta coefficients for the different perceived roles, with the unknown role as a reference category.

Discussion

This study sought answers to questions concerning teachers' self-efficacy to teach in ILEs, specifically in high-tech ILEs, to use high-tech equipment and how teachers perceive their role teaching in high-tech ILEs. Below follows a discussion of results through the perspective of previous, albeit few, studies, as well as the significance of our findings.

Table 5. Perceived roles of teachers, numbers of responses corresponding to each role, and representative responses.

Perceived role	*N*	Example answer
Active role	82	
Active supporting	67	'I see myself as a guide to the students, and I support them. My task is to listen, and to stimulate them to discover and be creative'.
Active learning	15	'Discovering along with the students, experimenting, being eager to learn'.
Passive role	7	'I would position myself in the background and make sure students stay focused on the task'.
Unknown role	95	'I do not know what a Fablab or Makerspace is. I need to find more information'. 'I have never visited a Fablab or Makerspace'. 'I do not know my role'.

Table 6. Estimates of the effects of perceived role in an informal learning environment on self-efficacy in using informal learning environments.

	β	SE	t	Sig.
Intercept	−.26	.09	−2.83	.005
Active role				
Active supporting	.43	.14	3.03	.003
Active learning	.64	.25	2.56	.011
Passive role	.04	.35	.11	.912

Table 7. Estimates of the effects of perceived role in an informal learning environment on self-efficacy in using technological equipment.

	β	SE	t	Sig.
Intercept	−.46	.08	−5.40	.000
Active role				
Active supporting	.97	.13	7.35	.000
Active learning	.67	.23	2.93	.004
Passive role	.35	.32	1.09	.277

Teachers' self-efficacy teaching in informal learning environments and in using high-tech equipment

We found that teachers reported moderate self-efficacy to teach in ILEs in general. These results are novel because we have not found any previous quantitative study investigating teachers' self-efficacy to use ILEs in their teaching, only the reports about teachers' lack of skills in this respect (e.g. Ertmer and Ottenbreit-Leftwich 2010; Griffin 2012; Tal, Bamberger, and Morag 2005). Our findings are promising, showing that STEM teachers are not negative towards teaching in ILEs as might be expected considering previous research on teacher skills. Instead, the results of this study are more in line with Song (2018), showing that with support, as in-service training, teachers might be prepared to take on the task of teaching in ILEs.

However, teachers' self-efficacy in using the high-tech equipment in the ILEs was reported as being low, indicating that teachers felt ill-prepared to use high-tech equipment. This is consistent with the findings of previous studies (Eriksson et al. 2018; Hasse 2017; Walan 2020; Wardrip and Brahms 2016), who argued that teachers need more knowledge about how to handle high-tech equipment. Based on our results, we can conclude that use of high-tech equipment is one of the most important hurdles for teachers to teach in high-tech ILEs, at least in Flanders and Sweden. However, teacher education programmes and guidance from, or collaboration with qualified personnel (e.g. Fablabs/Makerspaces staff) might enhance teachers' self-efficacy in environments with high-tech equipment, and they could be a way to improve STEM teachers' self-efficacy in using high-tech equipment, as also proposed by Griffin (2012) and Tal, Bamberger, and Morag (2005).

Differences in teachers' self-efficacy in teaching in high-tech informal learning environments related to background

Comparing teachers from Belgium (Flanders) and Sweden, we found some differences related to gender, which is of interest, because Makerspace activities are often seen as male pursuits (e.g. Eriksson et al. 2018). Male teachers in Flanders, but not in Sweden, reported a higher self-efficacy to teach in high-tech ILEs compared to female teachers. Although we have no straightforward explanation for this interaction effect, it could be the result of ILEs being more common and widespread in Sweden among male and female teachers. The results of previous studies (Al Bataineh and Anderson 2015; Woods et al. 2008) on this issue are inconsistent: some reports indicate that female teachers have higher levels of self-efficacy than males, and some show the opposite. It is, therefore, not yet possible to draw firm conclusions on whether male or female teachers have higher self-efficacy to use technological equipment, and these differences appear to be connected to cultural contexts. More studies are called for to investigate this issue further, especially since these kinds of ILEs still are quite new to most people (Peppler, Halverson, and Kafai 2016a).

Surprisingly, we did not find any effects of teaching experience on self-efficacy to use technology in any of the countries where this study took place. One might expect teachers with less experience to generally be younger and more familiar with modern technologies than their more experienced counterparts since for instance, experience has been argued as a factor of influence on teachers' self-efficacy in this respect (e.g. Al Bataineh and Anderson 2015; Vannatta and Fordham 2004). However, our data do not support this expectation. The results highlight that we should not assume that the use of technological equipment will be introduced into the school through younger teachers. These results seems to indicate that current in-service teacher education programmes in Flanders and Sweden do not provide teacher students learning opportunities with high-tech equipment, which calls for an update of these programmes if they intend to stay in tune with the STEM development in society. Hence, if we want teachers to be able to handle high-tech equipment in ILEs, professional development of in-service teachers, as well as preparation of pre-service teachers, are needed.

Teachers' perceived role when teaching in high-tech informal learning environments

As previously argued (Kajamaa, Kumpulainen, and Olkinuora 2020), few studies have investigated teachers' role in ILEs like Makerspaces, we investigated how teachers in our study perceived their role in ILEs. The teachers who perceived their role in ILEs as being active (i.e. focused on supporting, guiding, and learning alongside students) reported higher self-efficacy in these environments. This is not surprising, but it indicates that teachers' increased self-efficacy to teach in high-tech ILEs is linked to a role as a coach or fellow student. This role differs extensively from a traditional, more transmissive teacher role as lecturer, handling close-ended tasks with guided inquiry, where students are not to come up with questions themselves. What the results from two countries show is that there were some teachers who have adopted the role a teacher should have according to constructionism, namely being a facilitator and coach (e.g. Freeman et al. 2017).

Teachers who are acquainted with the physical and pedagogical environment of a Fablab or Makerspace may feel more certain about their role (which is more likely to be active) and have greater self-efficacy regarding both teaching in such environments and using the equipment that they offer. Since self-efficacy can be defined as a person's belief in his/her ability to succeed in a particular situation (Bandura 1993), this is consistent with the finding that uncertainty or insecurity regarding one's role in ILEs is linked to lower self-efficacy.

In our study, there were teachers who reported that they wanted to have a passive role or that they were uncertain of what role to take. These findings can be explained in two ways. It may be that this group of teachers were simply insufficiently familiar with ILEs, such as Fablabs and Makerspaces, and that they did not have knowledge about the constructionist learning tradition. If so, the teachers could be confused about their identity and role in these kind of environments (e.g. Campos, Soster, and Blikstein 2019; Petrich, Wilkinson, and Bevan 2013). Alternatively, a reason could be that the teachers, as argued by researchers (e.g. Wardrip and Brahms 2016; Tal, Bamberger, and Morag 2005), simply wanted to rely on staff in the ILEs to be in charge and chose a lay-back profile themselves.

If more teachers are to develop an interest in having an active role when teaching STEM at high-tech ILEs with their students and to develop their self-efficacy in this, teachers need more experience in doing so and maybe even some kind of teacher professional development course.

Song (2018) argued that the teachers in his study, even though they did not have any prior knowledge of Makerspaces, developed confidence in working with, for instance, 3D-printers in Makerspaces when they participated in hands-on and theoretically grounded professional learning activities. In professional development we need to develop teachers' skills and an identity in a way that they also can see themselves as taking an active role in order to align with the constructionist learning tradition of Fablabs/Makerspaces.

Limitations and future studies

The current study focused on Sweden and Belgium (Flanders) because of the importance to follow up national curricula changes. The results highlight that local, cultural, policy and curriculum contexts shape teachers' self-efficacy to teach STEM in high-tech ILEs, and these results should only be transferred to other cultural and policy contexts with caution.

We acknowledge that we relied on an online survey, which may have inflated the number of teachers reporting uncertainty about their role in ILEs. The participants in this study were recruited by contacting teachers attending teacher educational conferences and professional development courses, and via professional teacher and Fablab networks. Because we made no effort to control which of these teachers completed the questionnaire, the participants cannot be assumed to be representative of the population of teachers in general (they were contacted because of their connections to, or interest in high-tech ILE).

Furthermore, the study is not an exclusive survey of teachers who are accustomed to Fablab/Makerspace visits. However, we make no claims about the proportions of teachers adopting specific roles; instead, we focus on the existence of different roles and their relationship to self-efficacy. Therefore, the absolute number of teachers reporting an unknown role should not greatly affect the reliability or validity of our results. The use of an online survey can thus be considered an appropriate way to address our research questions, and we can safely assume that teachers who have never visited a Fablab/Makerspace, or are unfamiliar with the concept of ILE will be less ready for the future, in terms of self-efficacy teaching in these kinds of ILEs and in using high-tech equipment.

The relatively low R-square of our model, indicate that other variables than the ones included in the current study, also could explain differences among teachers. These might be for example their previous experiences with the subject and context, their interest in technology and attitudes toward technology. In future studies we recommend that these variables also should be investigated.

To generalise the findings presented here and better characterise between-country differences, additional countries should be included in future studies. There is also a need for further research to assess the impact of teaching education programmes on self-efficacy and perceived role in high-tech learning environments because the results presented here raise some points of concern relating to teachers' readiness to work in high-tech ILEs. Such studies could provide support for the development of research and teaching programmes to help improve teachers' readiness. It will also be necessary to conduct observational studies on the link between self-efficacy and actual active teaching behaviours rather than relying solely on self-reports if we want to find out more about teachers' readiness to teach in high-tech ILEs.

Conclusions and implications

In sum, we can conclude that teachers have moderate self-efficacy when teaching in ILEs (both in general and specifically, in Fablabs and Makerspaces), but they have low self-efficacy in using high-tech equipment that is present in such ILEs, with females having less self-efficacy than males in this respect, less in Flanders than in Sweden. Hence, female teachers could be discouraged to visit high tech ILEs as they might expect more difficulties in handling the equipment. This is important to consider and possibly provide additional support for female teachers teaching at Fablabs/ Makerspaces. In the same time it is important to recognize that our result show that there are many teachers of all categories with low self-efficacy using high tech equipment in ILEs making it important to reach out to all teachers in for example professional development efforts. We believe that this low self-efficacy is related to teachers' lack of knowledge and that this problem today is a major obstacle for teaching STEM at high-tech ILEs. However, via collaboration with staff in the ILEs this obstacle can be quite easily overcome, and it is more important that teachers' role can be focused on facilitating learning on the basis on constructionism (rather than handling the equipment).

Because the role that teachers perceive themselves to have at high-tech ILEs, as active coaches and co-creators or passive observers, is significantly connected to their self-efficacy beliefs, it is important to state that our results highlight the importance of providing teachers with learning experiences that allow them to build self-efficacy for teaching in ILEs. An important implication is therefore to provide such learning experiences in in-service and pre-service teacher education of STEM. Further, the correlation between an active role as a teacher and increased self-efficacy empirically supports the importance to develop teacher practices in line with constructionism in relation to teaching in high-tech ILEs, both in in-service and pre-service teacher education.

This study has provided an overview of the current trends and concerns regarding teaching in high-tech ILEs and invites researchers and policy makers to further prepare teachers for teaching STEM in such environments. Such preparation could, for instance, comprise discussions with teachers on constructionism, and thus, what kind of role teachers could have and how to prepare activities together with staff in the ILEs.

Acknowledgements

We thank all of those who responded to the questionnaire used in our study and also colleagues from the ARTIFEX project for fruitful discussions within the project.

Ethical and consent statements

All procedures performed with human subjects were in accordance with the ethical standards of the Swedish Research Council (SCR) and from the Belgian Research Council, Research Foundation – Flanders (FWO). Informed consent was obtained from all participants in the study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The authors claim that there are no competing interests. The study was conducted within the Erasmus+ 2017-1-BE02-KA201-034714 project ARTIFEX and was funded through that project.

ORCID

Jelle Boeve-De Pauw http://orcid.org/0000-0002-8496-096X
Haydée De Loof http://orcid.org/0000-0002-9810-7804
Susanne Walan http://orcid.org/0000-0002-9060-9973
Niklas Gericke http://orcid.org/0000-0001-8735-2102
Peter Van Petegem http://orcid.org/0000-0002-4078-7800

Ethical considerations

All procedures performed with human subjects were in accordance with the ethical standards of the Swedish Research Council (SCR) and from the Belgian Research Council, Research Foundation – Flanders (FWO). Informed consent was obtained from all participants in the study.

References

Al Bataineh, M., and S. Anderson. 2015. "Teachers' Perceptions of Competency Needed for Implementing Technology in the Classroom." *Contemporary Educational Technology* 6 (1): 38–61. doi:10.30935/cedtech/6138.

Andrews, M. E., M. Borrego, and A. Boklage. 2021. "Self-efficacy and Belonging: The Impact of a University Makerspace." *International Journal of STEM Education* 8 (24). doi:10.1186/s40594-021-00285-0.

Bandura, A. 1993. "Perceived Self-Efficacy in Cognitive Development and Functioning." *Educational Psychologist* 28 (2): 117–148. doi:10.1207/s15326985ep2802_3.

Bevan, B., J. P. Gutwil, M. Petrich, and K. Wilkinson. 2015. "Learning through STEM-rich Tinkering: Findings from a Jointly Negotiated Research Project Taken up in Practice." *Science Education* 99 (1): 98–120. doi:10.1002/sce.21151.

Blikstein, P. 2013. "Digital Fabrication and "Making" in Education: The Democratization of Invention." In *FabLabs: Of Machines, Makers, and Inventors*, edited by J. Walter-Herrmann and C. Büching. Bielefeld, Germany: Transcript 1–21 .

Braun, V., and V. Clarke. 2006. "Using Thematic Analysis in Psychology". *Qualitative Research in Psychology* 3 (2): 77–101. doi:10.1191/1478088706qp063oa.
Campos, F., T. Soster, and P. Blikstein 2019. "Sorry, I Was in Teacher Mode Today": Pivotal Tensions and Contradictory Discourses in real-world Implementations of School Makerspaces." In Proceedings of the 8th Annual Conference on Creativity and Fabrication in Education (Fablearn 2019). ACM, New York, NY, USA
Cavalcanti, G. 2013. *Is it a Hackerspace, Makerspace, TechShop or FabLab?* Accessed 1 September 2019. https://makezine.com/2013/05/22/the-difference-between-hackerspaces-Makerspaces-techshops-and-fablabs/
Cohen, L., L. Manion, and K. Morrison. 2011. *Research Methods in Education*. New York, NY: Routledge.
Davies, S. R. 2017. *Hackerspaces: Making the Maker Movement*. Cambridge, UK: Polity Press.
Department of Education. 2019. *STEM: Science, Technology, Engineering, Mathematics*. Retrieved from https://onderwijs.vlaanderen.be/nl/stem
Dougherty, D. 2013. "The Maker Mindset." In *Design, Make, Play. Growing the Next Generation of STEM Innovators*, edited by M. Honey and D.E. Kanter, 7–11. New York, NY: Routledge.
El-Deghaidy, H., and N. Mansour. 2015. "Science Teachers' Perceptions of STEM Education Possibilities and Challenges." *International Journal of Learning and Teaching* 1 (1): 51–54.
Eriksson, E., C. Heath, P. Ljungstrand, and P. Parnes. 2018. "Makerspace in school-Considerations from a large-scale National Testbed." *International Journal of Child-Computer Interaction* 16: 9–15. doi:10.1016/j.ijcci.2017.10.001.
Ertmer, P. A., and A. Ottenbreit-Leftwich. 2010. "Teacher Technology Change: How Knowledge, Confidence, Beliefs and Culture Intersect." *Journal of Research on Technology in Education* 42 (3): 255–284. doi:10.1080/15391523.2010.10782551.
European Council. 2022. *Definitions*. Retrieved from https://www.coe.int/en/web/european-youth-foundation/definitions
Freeman, A., S. Adams Becker, M. Cummins, A. Davies, and C. Hall Giesinger 2017. "*NMC/COSN Horizon Report: 2017 K-12 Education*." Austin, Texas: New Media Consortium.
Gentry, J. E., C. Baker, B. D. Thomas, C. Whitfield, and L. Garcia. 2014. "Transforming Technology Integration: An Instrument to Measure Educator's self-efficacy for Modelling 21st Century Skills." *National Teacher Education Journal* 7 (3): 31–38.
Gershenfeld, N. A. 2005. *Fab: The Coming Revolution on Your desktop-from Personal Computers to Personal Fabrication*. New York: Basic Books.
Godhe, A-L., P. Lilja, and N. Selwyn. 2019. "Making Sense of Making: Critical Issues in the Intergration of Maker Education into Schools." *Technology, Pedagogy and Education* 28 (3): 317–328. doi:10.1080/1475939X.2019.1610040.
Griffin, J. 2012. "Exploring and Scaffolding Learning, Interactions between Teachers, Students and Museum Educators." In *Understanding Interactions at Science Centers and Museums. Approaching Sociocultural Perspectives*, edited by E. Davidsson and A. Jakobsson. Rotterdam, the Netherlands: Sense Publishers 115–128 .
Guo, Y., C. McDonald Connor, Y. Yang, A.D. Roehring, and F. J. Morrison. 2012. "The Effects of Teacher Qualification, Teacher self-efficacy, and Classroom Practices on Fifth Graders' Literacy Outcomes." *Elementary School Journal* 113 (1): 3–24. doi:10.1086/665816.
Guskey, T. R. 1988. "Teacher Efficacy, self-concept, and Attitudes toward the Implementation of Instructional Innovation." *Teaching and Teacher Education* 4 (1): 63–69. doi:10.1016/0742-051X(88)90025-X.
Halverson, E. R., and K. M. Sheridan. 2014. "The Maker Movement in Education." *Harvard Educational Review* 84 (4): 495–504. doi:10.17763/haer.84.4.34j1g68140382063.
Harel, I., and S. E. Papert 1991. "*Constructionism*." Norwood, NJ: Ablex Publishing.
Hasse, C. 2017. "Technology Literacy for Teachers." *Oxford Review of Education* 43 (3): 365–378. doi:10.1080/03054985.2017.1305057.
International Technology Education Association. 2000/2007. *Standards for Technological Literacy: Content for the Study of Technology*. Reston, VA: ITEA.

Kajamaa, A., K. Kumpulainen, and H-R. Olkinuora. 2020. "Teachers Interventions in Students' Collaborative Work in a technology-rich Educational Makerspace." *British Journal of Educational Technology* 51 (2): 371–386. doi:10.1111/bjet.12837.

Kjällander, S., A. Åkerfeldt, A. Mannila, and P. Parnes. 2018. "Makerspaces across Setting: Didactic Design for Programming in Formal and Informal Teacher Education in the Nordic Countries." *Journal of Digital Learning in Teacher Education* 34 (1): 18–30. doi:10.1080/21532974.2017.1387831.

Knipprath, H., L. Thibaut, M.-P. Buyse, S. Ceuppens, H. De Loof, J. De Meester, L. Goovaerts, et al. 2018. "STEM Education in Flanders: How STEM School Aims to Foster STEM Literacy and a Positive Attitude Towards STEM." *IEEE Instrumentation & Measurement Magazine* 36–40.

Kulas, J. T., and A. A. Stachowski. 2013. "Respondent Rationale for neither Agreeing nor Disagreeing: Person and Item Contributors to Middle Category Endorsement Intent on Likert Personality Indicators." *Journal of Research in Personality* 47 (4): 254–262. doi:10.1016/j.jrp.2013.01.014.

Künsting, J., V. Neuber, and F. Lipowsky. 2016. "Teacher self-efficacy as a long-term Predictor of Instructional Quality in the Classroom." *European Journal of Psychology of Education* 31 (3): 299–322. doi:10.1007/s10212-015-0272-7.

Martinez, S. L., and G. S. Stager. 2013. "Invent to Learn: A Guide to Why Making Should Be in." In *Every Class*. Torrance, CA: Constructing Modern Knowledge Press.

Maslyk, J. 2016. *STEAM Makers. Fostering Creativity and Innovation in the Elementary Classroom*. California: SAGE Publication Ltd. Thousand Oaks.

Morag, O., and T. Tal. 2012. "Assessing Learning in the Outdoors with Field Trip in Natural Environments (Fine) Framework." *International Journal of Science Education* 34 (5): 745–777. doi:10.1080/09500693.2011.599046.

National Research Council. 2009. *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington, D.C.: National Academies Press.

Pajares, F. 1992. "Teachers' Beliefs and Educational Research: Cleaning up a Messy Construct." *Review of Educational Research* 62 (3): 307–332. doi:10.3102/00346543062003307.

Papert, S. 1993. "*The Children's Machine: Rethinking School in the Age of the Computers*." New York: Basic Books.

Peppler, K., E. R. Halverson, and Y. B. Kafai. 2016a. "*Makeology*. Makerspaces as Learning Environments." In *Volume*, 1–11. Vol 1. New York, NY: Routledge.

Peppler, K., E. R. Halverson, and Y. B. Kafai. 2016b. "Makeology." In *Makers as Learners*, 1–9. Vol 2. New York, NY: Routledge.

Petrich, M., K. Wilkinson, and B. Bevan. 2013. "It Looks like Fun, but are They Learning?" In *Design. Make. Play. Growing the Next Generation of STEM Innovators*, edited by M. Honey and D. E. Kanter, 50–70. New York, NY: Routledge.

Rennie, L. J. 2014. "Learning Science outside of School." In *Handbook of Research on Science Education*, edited by N. G. Lederman and S. K. Abell, 120–144. Vol 2. New York, NY: Routledge.

Resnick, M., and E. Rosenbaum. 2013. "Designing for Tinkerability." In *Design, Make, Play*, edited by M. Resnick and E. Rosenbaum, 163–181, New York, NY: Routledge.

Rosa, P., F. Ferretti, A. G. Pereira, F. Panella, and M. Wanner. 2017. *Overview of the Maker Movement in the European Union, EUR 28686*. Luxembourg: EN, Publications Office of the European Union.

Ryan, J. O., E. P. Clapp, J. Ross, and S. Tishman. 2016. "Making, Thinking and Understanding. A Dispositional Approach to maker-centered Learning." In *Makeology. Makers as Learners*, edited by K. Peppler, E. R. Halverson, and Y. B. Kafai, 29–44. Vol 2. New York, NY: Routledge.

Sheridan, K. M., E. R. Halverson, L. Brahms, B. K. Litts, L. Jacobs-Priebe, and T. Owens. 2014. "Learning in the Making: A Comparative Case Study of Three Makerspaces." *Harvard Educational Review* 84 (4): 505–531. doi:10.17763/haer.84.4.brr34733723j648u.

Skolverket. 2018. *Förändringar och digital kompetens i styrdokument*. Retrieved from https://www.skolverket.se/temasidor/digitalisering/digital-kompetens#h-Forandringaristyrdokumenten

Song, L. 2018. "Improving pre-service Teachers' self-efficacy on Technology Integration through Service Learning." *Canadian Journal of Action Research* 19 (1): 22–32. doi:10.33524/cjar.v19i1.373.

Stein, M. K., and M. C. Wang. 1988. "Teacher Development and School Improvement: The Process of Teacher Change." *Teaching and Teacher Education* 4 (2): 171–187. doi:10.1016/0742-051X(88)90016-9.

Taherdoost, H. 2016. "Validity and Reliability of the Research Instrument: How to Test the Validation of a questionnaire/survey in a Research." *International Journal of Academic Research in Management* 5 (3): 2296.

Tal, R., Y. Bamberger, and O. Morag. 2005. "Guided School Visits to Natural History Museums in Israel: Teachers' Roles." *Science Education* 89 (6): 920–935. doi:10.1002/sce.20070.

Tan, M. 2019. "When Makerspaces Meet School: Negotiating Tensions between Instruction and Construction." *Journal of Science Education and Technology* 28 (2): 75–89. doi:10.1007/s10956-018-9749-x.

Vannatta, R., and N. Fordham. 2004. "Teacher Dispositions as Predictors of Classroom Technology Use." *Journal of Research on Technology in Education* 36 (3): 253–271. doi:10.1080/15391523.2004.10782415.

Vinnova. 2018. *Makespace i skolan*. Retrieved from https://www.vinnova.se/p/Makerspace-i-skolan2/

Vossoughi, S., P. K. Hooper, and M. Escudé. 2016. "Making through the Lens of Culture and Power: Toward Transformative Visions for Educational Equity." *Harvard Educational Review* 86 (2): 206–232. doi:10.17763/0017-8055.86.2.206.

Vuorikari, R, A Ferrari, and Y Punie. 2019. "Makerspaces for Education and Training – Exploring Future Implications for Europe European Union." *Eur 29819*. EN, Publications Office of the European Union: Luxembourg. JRC117481

Walan, S., and N. Gericke. 2019. "Factors from Informal Learning Contributing to the Children's Interest in STEM – Experiences from the out-of-school Activity Called Children's University." *Research in Science & Technological Education*. doi:10.1080/02635143.2019.1667321.

Walan, S. 2020. "Transfer of Activities from Innovative Environments Such as Makerspaces to Classrooms." In *Science and Mathematics Education for 21 St Century Citizens. Challenges and Ways Forward*, edited by L. Leite, E. Oldham, A. S. Afonso, F. Viseu, L. Dourado, and M. H. Martinho, 111–129. New York: Nova Science Publishers, .

Wardrip, P. S., and L. Brahms. 2016. "Taking Making to School. A Model for Integrating Making into Classrooms." In *Makeology. Makerspaces as Learning Environments*, edited by K. Peppler, E. R. Halverson, and Y. B. Kafai, 97–106. Vol 1. New York, NY: Routledge.

Woods, M. L., G. G. Karp, H. Miao, and D. Perlman. 2008. "Physical Educators' Technology Competencies and Usage." *Physical Educator: A Magazine for the Profession* 65 (2): 82–99.

Woolfolk Hoy, A., and H. A. Davis. 2006. "Teacher self-efficacy and Its Influence on the Achievement of Adolescents". In *SE Beliefs of Adolescents*, edited by F. Pajares and T. Urdan, 1–45. Greenwich, CT: Information Age.