# Makerspaces in the Early Years

## A Literature Review

MakEY

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# INTRODUCTION

*Jackie Marsh*

There is little doubt that the digital age is impacting on the lives of society's youngest children. Across Europe, many children have access to digital technologies in homes and communities from birth (Chaudron et al., 2015). There is as yet, however, limited research on the digital literacy practices of children aged from birth to age eight (Burnett and Daniels, 2016; Holloway, Green and Livingstone, 2013). This is problematic, as there is an urgent need for populations to develop the skills and knowledge required to navigate a complex technological world. It is acknowledged that the capacity of a society to innovate is related to its investment in human capital in order to reform traditional industrial industries in line with technological developments (Castells and Himanen, 2014), hence it makes sense to focus on the related skills, knowledge and practices of individuals from an early age.

Whilst a range of work that has focused on the development and assessment of digital skills, such as the DIGCOMP study in Europe (Ferrari, 2013), to date, limited attention has been paid to development of the digital literacy skills of young children. Further, it is clear that there needs to be a multi-stakeholder approach to the task of ensuring that young children develop the skills and knowledge required for the digital age. Researchers, early years practitioners and industry partners need to collaborate in knowledge exchange and the co-creation of new pedagogies and learning environments, including the development of digital tools and solutions that offer children avenues for digital learning. It is also important that young children have opportunities to foster their creativity and develop the kinds of creative skills that are important for future employment, learning and leisure, such as creative design.

The MakEY project was set up to address these issues by examining the experiences of young children as they participate in creative activities in specially-designed spaces

termed 'makerspaces'. These are spaces that enable participants to create a range of artefacts using specialist tools and resources, such as electronics, laser cutters, 3D printers, in addition to everyday resources, both digital and non-digital. There has been interest in recent years in the role of 'making', the design and production of artefacts, texts and products (Blikstein, 2013; Dougherty, 2013; Johnson et al., 2015; Peppler, Halverson and Kafai, 2016), and the creation of fabrication labs, or 'makerspaces', in which children and young people use equipment such as 3D printers and laser cutters for these purposes. An NMC Horizon report suggests that such spaces have 'the potential to empower young people to become agents of change in their communities' (Johnson et al., 2015), although the extent to which this is the case is dependent upon the type of experiences young people have in makerspaces, and the extent to which they are able to build on these experiences outside of the spaces.

A maker culture is one in which the processes of creativity and innovation are key, and some have linked its genealogy to that of craftsmanship (Schrock, 2014), although contemporary maker culture is less focused on the acquisition of a set of specific craft skills over a long period of apprenticeship and more concerned with a general approach in which anyone with access to the right tools and resources can create (Hatch, 2013). Makerspaces are part of the move to a 'DIY' culture in which citizens take the initiative and become more self-sufficient, made possible through the development of new digital tools and practices (Knobel and Lankshear, 2010). Rather than this being experienced as an individual process, however, makerspaces emphasise collaboration and sharing.

The use of the term 'hacker' has historically been linked to practices of subversion and transgression (Morozov, 2014); however, the word has more recently been incorporated into the notion of a maker culture in which the ethics of open access, creativity and innovation are key. There are, however, still conceptual and ideological differences between the two. Schrock suggests that, 'Rather than hacking's strategic to bring about differences (an outcome), making is more concerned with an ongoing process and the satisfaction that comes from it' (2014: 9-10, author's italics). Hacking is therefore related to 'tinkering', to the deconstruction and reconstruction of existing artefacts and making related to the creation of new products. In relation to this paper, the emphasis is on makerspaces, spaces in which young children can use a range of technologies, in addition

to non-digital tools and hardware, to create new artefacts and also to reconstruct existing artefacts – thus, making, hacking and tinkering.

It has been argued that there is a variety of benefits to be accrued from participating in makerspaces. First, individuals develop a range of skills using a variety of tools as they hack and make. The use of constructivist and experiential learning theories has supported accounts of learning by doing (Shrock, 2014) in which children develop the ability to design and produce a range of outputs. These may include the use of technologies. For example, Kafai, Fields and Searle (2014) document that children creating wearable textiles, 'e-textiles', learn how computers and electronics work (p.542). In relation to literacies, Santo (2011; 2013) contends that critical thinking is developed through participating in 'hacker literacies', which is described as a process of revising and being inventive with texts that are found on online sites such as blogs. Engagement in hacking, tinkering and making may, therefore, develop a range of '21st century' literacy skills (Jenkins et al., 2006) that are crucial to future employment and leisure opportunities, although it is important to refrain from an over-celebratory account of makerspaces and acknowledge the challenges that participants might face when using such spaces. Whilst positive claims are made about the potential for the Maker movement to contribute to learning, there is little research that has been undertaken in relation to makerspaces within early years educational contexts. Peppler, Halverson, & Kafai (2016) have pointed to the way in which much of the work on makerspaces to date has focused on adolescents and adults, and it is clear that certain demographic groups have been privileged in these projects, such as affluent groups and males (Blikstein & Worsley, 2016).

The aim of this review of the literature is to identify what we already know about the engagement of children aged under eight in makerspaces. Given the limited literature in the area, the review takes a broader look at makerspaces for older children where relevant. This is not a systematic review; its aim is not to offer an exhaustive account of all of the research conducted in the area. Rather, this narrative review provides an introduction to key aspects of research on makerspaces and enables the identification of themes dominant in the field, and those areas where more research is needed in order to extend knowledge of the value of makerspaces for early childhood. Each section is written by different members of the MakEY research team. The sections relate to the three areas

identified by Peppler, Halverson and Kafai (2016) as characteristic of much of the work in the field – makerspaces, making and makers – but themes and issues that cross-cut each of these areas are also addressed.

In this first section of the review, we identify some of the key rationale for the provision of makerspaces as an educational intervention to develop digital literacy, provide a brief historical overview of the Maker movement and then explore the relation between makerspaces and entrepreneurial education. The second section of the review considers makerspaces in different settings and identifies the work that has been conducted in relation to children aged eight and under. In the third section of the review, the value of making for various disciplinary areas is considered, as well as examining the more holistic impact of makerspaces in terms of inter-disciplinary learning. In the fourth section, we address a range of issues relating to identity (ethnicity, class and gender) and makerspaces, and the fifth section provides a conclusion to the review, identifying key questions that remain unanswered.

Before moving on to the review, it is worth outlining here some of the key concepts that inform the MakEY project, which inform the approach taken. First, the project includes a particular focus on digital literacy. The term 'digital literacy' is used to refer to the literacy practices of young children as they are undertaken across media, which involves 'accessing, using and analysing digital texts and artefacts in addition to their production and dissemination' (Sefton Green et al., 2016: 15). Drawing on Green's 3D (1998) model of literacy, we argue that there are three elements involved in considering digital literacy as a social practice – the operational (skills needed to write, produce, read and understand texts and artefacts), the cultural (understanding how digital literacy operates within a specific social and cultural context) and the critical (for example, understanding how power works within texts). Children need to develop skills and understanding across all three of these dimensions if they are to develop as digitally literate citizens of the twenty-first century.

In Colvert's (2015) recent research on the use of alternate reality games in primary classrooms, she proposed that in addition to considering the operational, cultural and critical domains, attention needs to be paid to the way in which design, production,

distribution and interpretation operate in the process of making. In the design stage, children develop the skills required to conceptualise their text/ artefact/ message, which may involve computer design skills. The production stage requires children to understand the affordances of the modes and media they are using to materialise their designs, and then they need to consider how their text/ artefact/ message will be distributed to others, through digital or non-digital means. Finally, texts and artefacts are interpreted by the audience and through this process, the designer may acquire important knowledge that can inform future production. In the MakEY project, when tracing children's changing digital literacy skills and knowledge, each of these stages in the meaning-making process will be considered. For example, as children create in makerspaces, they may need to draw on computational knowledge, an operational skill, to inform their production and it will be important to understand how this knowledge can be developed in context.

The MakEY project also focuses on children's creativity in makerspaces. Creativity is an important consideration of how young children learn. Creativity can involve possibility thinking, problem-solving and logic, all important in creating new knowledge (Sylva, Bruner and Genova, 1976). Creativity is not disciplinary-specific, and creative expression in makerspaces can cross, and/ or integrate, STEM with the arts and humanities. The project will also inform an understanding of children as creative designers. Design is a process that involves choosing modes and media in the meaning-making process, informed by an understanding of the affordances of those modes and media (Kress, 2010). Some research has been undertaken in this area that indicates that young children can become competent multimodal and multimedia designers, and re-designers, if they are provided with appropriate resources and support (Wohlwend, 2015).

It is important to note that when studying young children's creativity in makerspaces, it needs to be acknowledged that digital and non-digital practices are intimately related, and that practices will be fluid across domains. MakEY is interested in digital making, but we recognise that much of children's making may well take non-digital forms, and we are interested in the creativity embedded in these practices too. Rather than pose a false dichotomy between digital and non-digital making, the project will explore young children's making in a range of forms and across physical and virtual domains, and it will draw out

the implications of some project outputs for children's digital literacy skills and knowledge, given the significance of this area for 21st century learning.

In the first section of the review, however, we move away from the consideration of any specific subject area or set of skills and consider the origins of the Maker Movement and its relation to educational theory and practice.

# SECTION ONE
## THE MAKER MOVEMENT AND EDUCATIONAL PRACTICE

In this section, the history of makerspaces is outlined, and an etymology of key terms offered. In addition, the section considers the educational value of makerspaces and explores some of the educational philosophies that might inform their use.

### 1.1 MAKERSPACES – WHY THEY ARE IMPORTANT FOR DIGITAL LITERACY EDUCATION

*Kristiina Kumpulainen*

The importance of digital literacies for social inclusion, quality of life, success in the labour market and economic growth is widely recognised. There is an urgent need for every citizen to develop the knowledge, skills and attitudes required to participate in a complex and increasingly digitised society for personal and societal prosperity. According to the Digital Competence framework prepared by the European Commission[1], the key areas of digital competence are Information and data literacy, Communication and collaboration, Digital content creation, Safety, and Problem solving. In these policy documents, the definition of digital competence underscores confident, productive, creative and critical usage of digital technologies for diverse purposes in various social contexts and with various tools (Ala-Mutka, 2011). Moreover, these areas of digital competence are often viewed as part of the so-called transversal 21st century skill set that every citizen should be entitled to develop. Digital competencies are thus seen as intertwined with other transversal skill sets, including critical thinking skills and learning-to-learn, interaction and expression, multiliteracy, working life skills and entrepreneurship, as well as social participation and influence (FNBE, 2014). In our MaKEY project, we refer to these

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[1] (https://ec.europa.eu/jrc/en/digcomp/digital-competence-framework)

competencies as digital literacy to underscore their social and cultural nature, entailing the literacy practices, such as communication, expression, collaboration and advocacy, required for full participation in today's knowledge society (Sefton-Green et al., 2016).

Recent research shows that many children and young people in Europe have access to various media, digital tools, online sites and apps in their homes and communities (European Commission, 2013; [2]). The integration of digital tools into early years and primary classrooms has also increased due to the availability and affordability of computers, mobile phones, tablets and other similar technologies (Yelland & Gilbert, 2013). However, the nature of digital literacy practices used by many young people throughout Europe is found to be inadequate (European Commission, 2013). Young people are reported to be adept at using technologies for operational purposes, but they generally lack more advanced literacies, such as critical literacy (Ala-Mutka, 2011). Overall, these findings indicate that mere exposure to technology does not equate with the development of more advanced digital literacies (Li et al., 2016). Moreover, not all young people have equal opportunities to use digital technologies fully due to various social and cultural factors, lack of interest and confidence or social support (Ala-Mutka, 2011). Research also shows uneven provision of digitally-enhanced learning opportunities for children in formal educational settings (Palaiologou, 2014; Ilomäki & Lakkala, 2011 [3]).

Whilst a range of European work has focused on the development of digital literacies for all citizens (e.g. Ferrari, 2013), scant attention has been paid to educational activities that position children as active, creative and critical investigators of and with digital technologies. At present, there is a dearth of knowledge on creating learning opportunities for digital literacies that are inclusive for diverse learners with different capabilities and interests, and that are able to accommodate their different personal situations and objectives and combine, for example, formal and everyday learning practices (Kumpulainen, & Erstad, 2016; Kumpulainen, & Mikkola, 2016). In sum, these realities point to the urgent need for the development and research of novel pedagogies and

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[2] Suoninen, A. (2014). Lasten mediabarometri 2014. 0-8 vuotiaiden mediankäyttö ja sen muutokset vuodesta 2010. Nuorisotutkimusseura, verkkojulkaisuja 75.

[3] Ilomäki, L., & Lakkala M. (2011). Koulu, digitaalinen teknologia ja toimivat käytännöt. In M. Teoksessa, Kankaanranta & S. Vahtivuori-Hänninen (toim.), *Opetusteknologia koulun arjessa II* (pp.47–67). Jyväskylä: Koulutuksen tutkimuslaitos, Jyväskylän yliopisto.

learning environments to enhance every young person's digital literacies in meaningful, authentic and consequential ways.

### 1.1.1 Makerspaces and Children's Development of Digital Literacies

One of the most recent societal phenomena arousing educational interest internationally is the growth of 'makerspaces'. Makerspaces are listed among the key trends accelerating technology adoption in K-12 education by the international Horizon Project (http://www.nmc.org/nmc-horizon/). Also, in Finland, there is growing interest in makerspaces (e.g. Sitra, 2015[4]) and in democratising educational opportunities for digital and other transversal 21st century competencies.

Makerspaces prescribe a model of learning-by-doing in which individuals can work on creative design projects that are personally and/or collectively meaningful. The possibility to play with material objects is considered to act as "a social glue" for people to come together and engage in collaborative and creative endeavours (e.g. Gauntlett, 2011; Honey, & Kanter, 2013; Ingold, 2013). It follows that social interactions and learning practices in makerspaces often cross divisions such as age, gender or level of formal education and/or expertise (e.g. Halverson & Sheridan, 2014). In sum, making activities account for a complex set of socially and materially mediated practices that encompass not only processes of creating specific artefacts supported by a wide range of technologies and media, but also emotional, relational and cultural processes surrounding their use and construction.

A variety of benefits have been proposed as accruing from participating in making activities based on intellectual traditions of cognitive psychology, constructivism, experiential learning and design theory (Dewey, 1902; Freire; 1970; Papert, 1980). Research suggests that hands-on experimentation and production across multiple media and digital contents supports students' creative and critical engagement in disciplinary and transversal learning with various digital technologies and media (Hughes, 2017; Ratto, 2011). Existing research suggests that making activities have the potential to support

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[4] Sitra (2015). Maa, jossa kaikki rakastavat oppimista. Helsinki: Sitra.

young people's creative and improvisational problem-solving, encourage students' agency, persistence and self-efficacy, and enrich young people's ideas and understanding in STEM and beyond (Bevan et al., 2016). Research also suggests how making activities can enhance peer collaboration and transform the traditional roles of teacher/other adult experts and students, enabling participants to develop and draw on each other's relative expertise (Vossoughi & Bevan, 2014; Reed, et al., 2016). In addition to these academic goals, research on makerspaces in a children's hospital points out their emancipatory and healing value in supporting young patients to feel more agentive in taking charge of their environment, as well as of their learning and wellbeing (Krishnan, 2015).

Kafai, Fields and Searle (2014), for instance, examined students' engagement in one type of making activity, that of creating electronic textiles. In a similar fashion to Peppler and Glosson (2013), they conclude that by making wearable textiles, students gain a better understanding of the functions of computers and other tools involved in the process. Similarly, by means of designing games, making stories and animations and sharing them with others, children learn not only computational thinking but also come to understand the cultural and social nature of digital literacy practices (Kafai, & Burke, 2014; Portelance, Strawhacker, & Bers, 2015). In relation to critical literacies, Santo (2011; 2013) points out that when children take part in 'hacker literacies' they learn to approach technologies not merely as tools for self-expression and production but also learn to reflect on and critically evaluate the societal impact of technology use. In conclusion, as children engage in making activities, they appear to learn to draw on various knowledge(s) and skills (operational) to inform their creative production (cultural) and thus come to understand the ways in which these knowledges are embedded in larger sociocultural contexts (critical).

At the same time, available educational research on makerspaces has pointed out critical features that need to be addressed when considering their educational value (Peppler, & Bender, 2014). For instance, makerspaces have been criticized for their narrowly defined goals, and thus failing to attract and engage the broader population of young people (Blikstein, & Worsley, 2016). Research has also warned about an erroneous dichotomisation between abstract thinking and play, a general ethos of more "doing" and less "thinking and reflection", and about a dismissive stance towards the documentation and assessment of learners' engagement and learning in makerspaces (Kumpulainen,

Mikkola, & Rajala, 2017). Also, as Blikstein (2013) points out, educators need to move away from the simple demonstration projects typically associated with makerspaces and move toward learning that is more meaningful and contextualised. In sum, existing research calls for quality and inclusivity in makerspaces and making activities, and it urges further investigation into makerspaces as they relate to creating equitable and deep learning experiences for all children and young people.

## 1.1.2 Conclusion

Based on reading recent research and policy documents, there are worldwide concerns that our educational systems are outdated and failing to promote the digital literacies necessary to adequately prepare our children for the future. One of the major concerns is to ensure that every young person is equipped early on with adequate digital literacies to support their academic and civic engagement and lifelong learning opportunities. In many European countries, there is an urgent need to enhance young people's digital literacies in connection with other disciplinary and 21st century skill sets. Our MakEY project, with its interest in understanding the potential of makerspaces for enhancing young children's digital literacy and creativity across various settings, is directed towards these ends.
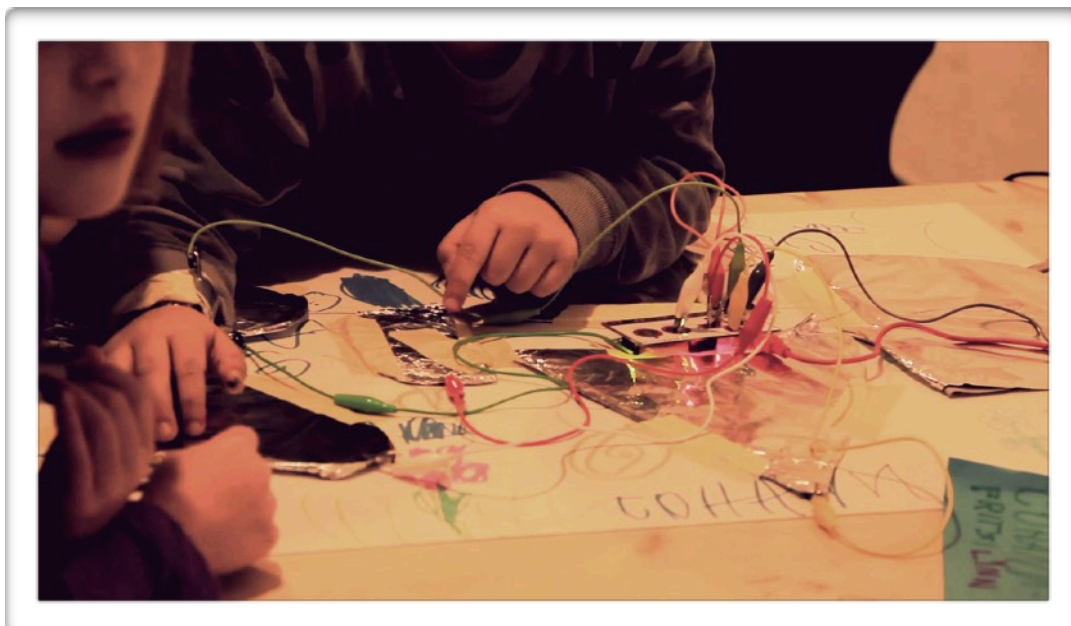
## 1.2   THE HISTORY OF THE MAKER MOVEMENT

*George Marusteru*

In order to define makerspace, we must first define the activity of "making", the identity of a "maker" and the social movement that is referred to as the "Maker movement", in addition to considering similar movements, identities (hacker, tinkerer) and spaces (hackerspace, fablab, techshop).

'Hacking'' was popularised by the Whole Earth Catalog publisher Stewart Brand and intended to connect technological enthusiasm with counter-cultural and rebellious tendencies (Morozov, 2014). The term was first used in the late 1950s by the Tech Model Railroad Club, a student-run club at MIT in the USA. They state that:

> We at TMRC use the term "hacker" only in its original meaning, someone who applies ingenuity to create a clever result, called a "hack". The essence of a "hack" is that it is done quickly, and is usually inelegant. It accomplishes the desired goal without changing the design of the system it is embedded in. Despite often being at odds with the design of the larger system, a hack is generally quite clever and effective.
>
> http://tmrc.mit.edu/hackers-ref.html

They suggest that this usage contrasts with the contemporary use of the term, which is often used to convey a negative picture of an individual who is intent on disrupting the status quo. Steven Levy (1984) in *Hackers: Heroes of the Computer Revolution* attempts to identify the core elements of the 'hacker ethic':

1. Access to computers–and anything which might teach you something about the way the world works–should be unlimited and total. Always yield to the Hands-on Imperative!
2. All information should be free.
3. Mistrust authority–promote decentralization.
4. Hackers should be judged by their hacking, not bogus criteria such as degrees, age, race or position.

5. You can create art and beauty on a computer.
6. Computers can change your life for the better.

<div align="right">(Levy, 1984: 40–45).</div>

The best-known and oldest hacker association, Chaos Computing Club (abbreviated as CCC), was founded in 1981 in Germany, hosted its first Chaos Communication Congress in 1984 and currently has more than 5,500 members. The first hackerpace, C-Base, was launched in 1995 in Berlin. These first hackerspaces began as spaces where computer programmers could collectively meet, work and share infrastructure. They would 'hack' technology in order to try to make it do something that it wasn't meant to do. The terms 'hacking' or 'hacker' in a computer context soon evolved and expanded to the practice of hacking of physical objects as we know it today, and extended even further into other areas, hence the use of terms such as "life hacks". Over the years, the cost of maker tools, such as 3D printers, desktop laser cutters and CNC routers, became more affordable, and hackerspaces naturally evolved into makerspaces.

A common definition for hackerspaces is: 'a community-operated workspace where people with common interests, often in computers, technology, science and digital art can meet, socialize and collaborate'[5] (Henry, 2012). Some years after the European trend began, in the early years of the twenty-first century, a number of hackers from the US visited CCC in Germany and went back to the States to set up organisations such as NYC Resistor (2007), HacDC (2007) and Noisebridge (2008).

Martin (2015:32) argues that '"Making", as a term, has been popularized by Make Magazine and Maker Faire (Anderson, 2013)', and suggests that it started with the founding of Make Magazine in 2005. The first Maker Faire was held in San Mateo, California in 2006, expanding on the culture of DIY and 'making' by also creating spaces where people could display, share and popularise their creations. Cavalcanti (2013) reports that the founder of MAKE magazine, Dale Dougherty, originally wished to call the magazine HACK, but his daughter did not like the term and suggested instead that it should be MAKE, to reflect the fact that making was a popular activity. Thus the term 'Maker Movement' emerged from these origins.

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[5] https://en.wikipedia.org/wiki/Hackerspace

A maker culture is one in which processes of creativity and innovation are key, and some have linked its genealogy to that of craftsmanship (Schrock, 2014), although contemporary maker culture is less focused on the acquisition of a set of specific craft skills over a long period of apprenticeship and more concerned with a general approach in which anyone with access to the right tools and resources can create. The Maker Manifesto (Hatch 2013) attempts to identify some of the principles that are representative of the 'Maker Movement':

> MAKE – Making is fundamental to what it means to be human. We must make, create and express ourselves to feel whole. There is something unique about making physical things. These things are like little pieces of us and seem to embody portions of our souls.
>
> SHARE – Sharing what you have made and what you know about making with others is the method by which a maker's feeling of wholeness is achieved. You cannot make and not share.
>
> GIVE – There are few things more selfless and satisfying than giving away something you have made. You must have access to the right tools for the project to hand. Invest in and develop local access to the tools you need to do the making you want to do.
>
> LEARN – You must learn to make. You must always seek to learn more about your making. You may become a journeyman or master craftsman, but you will still learn, want to learn and push yourself to learn new techniques, materials and processes. Building a lifelong learning path ensures a rich and rewarding making life and, importantly, enables one to share.
>
> TOOL UP – You must have access to the right tools for the project to hand. Invest in and develop local access to the tools you need to do the making you want to do. Tools for making have never been cheaper, easier to use or more powerful.
>
> PLAY – Be playful with what you are making, and you will be surprised, excited and proud of what you discover.
>
> PARTICIPATE – Join the Maker Movement and reach out to those around you who are discovering the joy of making. Hold seminars, parties, events, maker days, fairs, expos, classes and dinners with and for other makers in your community.

SUPPORT - This is a movement, and it requires emotional, intellectual, financial, political and institutional support. The best hope for improving the world is us, and we are responsible for making a better future.

CHANGE - Embrace the change that will naturally occur as you go on the maker journey. Since making is fundamental to what it means to be human, you will become a more complete version of you as you make.

(Hatch, 2013: 1 ff.)

Hatch was the founder of Techshop, a chain of for-profit makerspaces that began in 2006 in California, USA. They describe themselves as 'an open-access, DIY workshop and fabrication studio. We are a community-based space where entrepreneurs, artists, makers, teachers, and students come together to learn and work together'[6]. Just before Techshops emerged, Fab Labs appeared. FabLabs were started by Professor Neil Gershenfeld in 2002 at the Center for Bits and Atoms in MIT's Media Lab as pedagogical environments that would allow everyday people to solve their own problems by producing (rather than purchasing or outsourcing) the tools they need (Halverson & Sheriddan, 2014). They have a specific set of rules and charter to follow and are governed by the FabFoundation. In this sense, we can consider FabLab and TechShop as trademarked names for a particular type of makerspace.

This brief historical overview would suggest that there have been changes as to purpose and focus of makerspaces in recent years, with a focus on activism and the democratisation of the production process in many makerspaces in the past, and the emphasis on makerspaces as sites for individual expression and creativity in contemporary society. Indeed, Willett (2016: 316) argues that 'the lack of a DIY ethic is a major source of critique of current DIY projects and groups', as some of of them are funded by corporate institutions, and appear to be driven by sets of very different values to those that led to the creation of hacker spaces in the past.

Nevertheless, it could be argued that the 'Maker Movement' is an expansion or popularisation of the earlier 'Hacker Movement', as they share many of the same principles and approaches to working and learning, utilising 'design-make-play learning

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[6] http://www.techshop.ws.

methodologies', as Honey and Kanter (2013) define them. In practice, these spaces (makerspaces and hackerspaces) are also, in many cases, indistinguishable in terms of equipment and techniques, hackers having expanded towards fabrication and makers towards software and programming. There are, however, still some conceptual and ideological differences between making and hacking. Schrock suggests that, 'Rather than hacking's strategic to bring about differences (an outcome), making is more concerned with an ongoing process and the satisfaction that comes from it' (2014: 9-10, author's italics). Hacking is therefore related to 'tinkering', to the deconstruction and reconstruction of existing artefacts and making related to the creation of new products. In relation to the MakEY project, the emphasis is on makerspaces in which young children can use a range of digital technologies, in addition to non-digital tools and hardware, to create new artefacts and also to reconstruct existing ones – thus, making, hacking and tinkering.

Given the grassroots nature of makerspaces, there remains the question of why they should be considered in terms of making a contribution to early learning. In the next section of the review, we consider some of the key arguments made in this regard.

## 1.3 INNOVATION AND ENTREPRENEURIAL EDUCATION (IEE) AND MAKERSPACES

*Svanborg R. Jónsdóttir*

Creativity and innovation are key to engagement in makerspaces, and the concepts are closely intertwined. We could not be creative without some sort of innovativeness, something new or unusual. Innovation does not come about without creative thinking, and depending on how innovation is defined, it requires creative actions. Some scholars do not make a distinction between innovation and creativity (Georgsdottir, Lubart, & Getz 2003; Weisberg 2003).

The curricular subject *Innovation and Entrepreneurial Education* (IEE) has been developing in Iceland since the early 1990s. In compulsory school settings (6–16-year-old

students) IEE is more commonly called *Innovation Education,* and on the upper-secondary level *Entrepreneurial Education* or *Enterpreneurship Education*. On both school levels and on a preschool level, IEE has been effective in enhancing students´ innovative capacities and entrepreneurial spirit (Jónsdóttir et al., 2008; Sara M. Ólafsdóttir and Svanborg R. Jónsdóttir, 2016; Svanborg R. Jónsdóttir and Allyson Macdonald, 2013; Jónsdóttir and Macdonald, 2014). IEE is a curricular area that is about using creativity and knowledge to solve problems that learners themselves identify and analyse. It aims to develop critical and creative thinking in design, science, technology, marketing and enterprise. The main emphasis in IEE is on enhancing creative skills and actualising learner ideas with their active participation (Jónsdóttir and Gunnarsdóttir, 2017). The majority of Innovation Education lessons are offered to students on lower compulsory levels, mainly students 7–12 years old. It will be of value to explore what could be applied to the education of younger children.

In spite of good examples from and effective implementation of IEE in Iceland, it has not come about without facing certain challenges. IEE requires working across traditional subjects and boundaries, such as school society, and acknowledging both school knowledge and everyday knowledge (Jónsdóttir & Macdonald, 2013). Teachers are often bound by the traditional subject organisation of school knowledge and need support to master the balance of freedom and structure that IEE requires when integrating knowledge and crossing boundaries of different kinds. Other challenges include the relationships among teachers and between teachers and learners. IEE as experienced by learners, teachers and administrators shows certain characteristics. It has weak boundaries and is an elastic phenomenon offering freedom and flexibility. The opportunities introduced through the aims of IEE have been seen to enhance learners' creativity and innovativeness and strengthen their capacity for action in their lives and society.

Open communication between
teacher and learners
Weak framing

PROGRESSIVE
pedagogy

EMANCIPATORY
pedagogy

Distinct roles of
teacher and
learners
Strong
classification

Similar roles of
teacher and
learners
Weak
Classification

CONTROLLED
pedagogy

TRANSMISSIVE
pedagogy

Directive communication
between teacher and learners
Strong framing
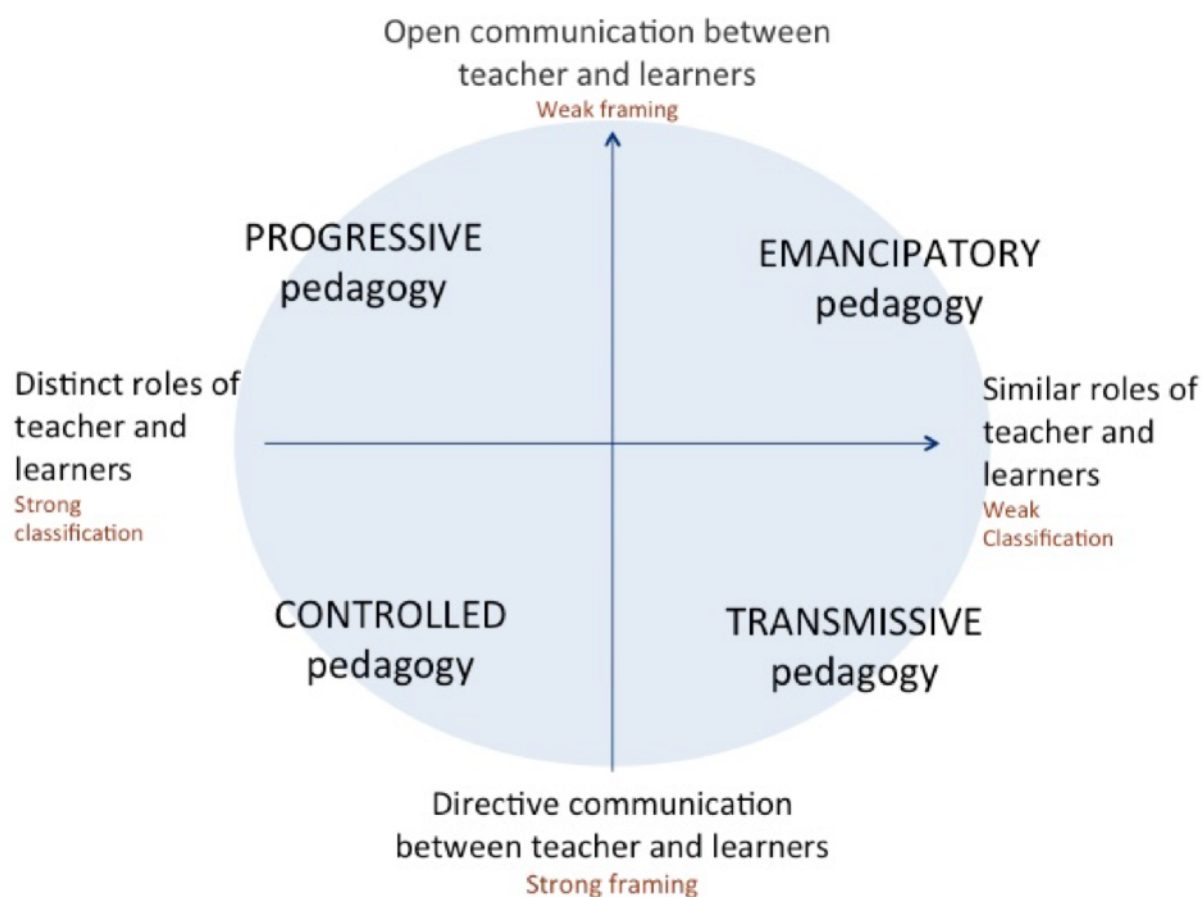
**Figure 1: Pedagogies analysed with classification and framing**
**(adapted from Jónsdóttir & Macdonald, 2013)**

Jónsdóttir´s research on IEE, using criteria developed from Bernstein's (Bernstein, 2000) concepts of classification and framing revealed four types of pedagogy: *transmissive, controlled*, *progressive* and *emancipatory* (Jónsdóttir and Macdonald, 2013; Jónsdóttir and Gunnarsdóttir, 2017) (see Fig. 1). Teachers display different strengths of framing (who controls) in IEE lessons, with an inherent tendency towards strong framing. The weak framing advocated by IEE and its weak classification as an area of knowledge make special demands on teachers and schools traditionally built on strongly classified subjects and roles and on strong framing. When the practices of 13 IEE teachers were scrutinised in light of classification and framing, four modes of IEE pedagogy could be identified: *emancipatory*, *progressive, controlled* and *transmissive.* The emancipatory mode is the one most in line with the ideology of IEE, but teachers working in progressive mode could

adapt or move into the emancipatory mode. The emancipatory pedagogy analysed as the pedagogy at the heart of IEE allows learners the most freedom and agency, the roles of teachers and learners are on equal levels and with the same communication as between colleagues. The controlled mode allows the least learner agency and limited creativity, but it may be a starting point for some teachers who could move on to the progressive mode and towards the emancipatory mode. It seems unlikely that teachers apply the transmissive mode in IEE as it builds on strong framing of communication and weak classification of roles, though it is an interesting alternative in light of the emphasis on individualised learning.

The findings show that IEE teachers have to build on or acquire approaches and views that are sometimes different from what they are used to. They have to develop an 'artistic approach' (Eisner, 2002) to teaching and holistic thinking that can easily override boundaries of subjects and social relations. They must display constraint and be able to stand back when learners were developing their ideas, and some teachers tend to control many aspects of IEE lessons with strong and sometimes very strong framing. Awareness of the tendency to control can be acquired by reflecting on teaching in IEE with a focus on who controls whom and what (Jónsdóttir & Gunnarsdóttir, 2017; Jónsdóttir & Macdonald, 2013). Thirteen innovation education teachers were found to be at different levels of adapting the IEE pedagogy, depending on their training, the school ethos and their personal and professional inclinations. An artistic orientation with mixed framing seems to help some teachers deal with the balance needed between freedom and structure in the classroom, where teachers seek to give value to learners' voices, elicit tacit knowledge of learners and situate learning in context. This capacity of teachers to allow enough freedom, accepting the role of the 'flexible teacher' in order to enhance learner agency and creativity within reasonable boundaries and in different contexts, seems to make the greatest difference in realising the potential of IEE.

What is expected of teachers working with children and young people and how those expectations fit their teaching philosophies do matter and need to be understood by each and every teacher (Darling-Hammond 1999). Helping teachers and mentors to make their educational philosophies visible and face possible *chaos angst* when taking on assisting learners in creative spaces can be supported by having access to specialist support and/ or peer consultation (Jónsdóttir & Gunnarsdóttir, 2017). These principles will be important

to consider as more educational institutions develop a makerspace approach to reaching and learning.

It seems that IEE builds on the foundations of early learning in terms of its emphasis on emancipatory pedagogy. The MakEY project is focused on the early years of learning and thus, in the final part of Section One of this literature review, we move on to consider how makerspaces embed the key principles underpinning many early childhood educational philosophies.

## 1.4 EARLY CHILDHOOD EDUCATIONAL PHILOSOPHIES/ PRINCIPLES AND THEIR RELATION TO MAKERSPACES

*Jackie Marsh*

Whilst global contexts for early childhood education differ, there appears to be a great degree of consistency in the principles that underpin this provision in terms of the educational philosophies embedded in curricula and pedagogy. In 2002, Betram and Pascal undertook a review of the principles underpinning early years provision in 20 countries, including some of the countries involved in the MakEY project (Australia, France, Germany, the UK and the USA). This International Review of Curriculum and Assessment (INCA) found that there was broad agreement on the approaches that should be adopted in relation to early childhood education and care, which included recognition of the importance of: child-centredness; play; social and emotional development and empowerment of the child to be an autonomous learner (Betram and Pascal, 2002: 35). These four areas will be considered in relation to the educational philosophies underpinning the approaches adopted in makerspaces in order to identify the degree of overlap between them. Given that the MakEY project is focused on the provision of makerspaces for children aged eight and under, this would appear to be an important undertaking.

### 1.4.1 Child-Centredness

Despite this being the first of the principles Bertram and Pascal (2002) identify as informing global approaches to early childhood education, there is little consistency in the understanding of this term, with Chung and Walsh (2000) identifying more than 40 different meanings of the phrase in a review of related early childhood literature. They argue that there have been three major interpretations of the term over time, from Froebel's (1899) notion that the child is at the centre of his/her world, to a developmental understanding of the term as denoting that schooling should focus on the child, and more recent emphasis on the child as an active agent in his/ her own learning (Chung and Walsh, 2000: 229). Nevertheless, the term is generally agreed as denoting educational

practice that begins with an understanding of the needs and individual interests of the child, one that emphasises the personalisation of the learning context.

It can be argued that makerspaces foster personalised learning by enabling participants to pursue learning opportunities that suit their interests. Of course, this is constrained by the context of a particular makerspace, and the resources it offers, but the most effective makerspaces enable users to pursue their own passions (Hsu, Baldwin & Ching, 2017)

## 1.4.2 The Importance of Play

Central to many early childhood philosophies is the phenomenon of play, with attention paid to the link between play, creativity and learning (Broadhead, 2006). Vygotsky argues that play is inherently creative:

> We can identify creative processes in children at the very earliest ages, especially in their play. A child who sits astride a stick and pretends to be riding a horse; a little girl who plays with a doll and imagines she is its mother; a boy who in his games becomes a pirate, a soldier, or a sailor, all these children at play represent examples of the most authentic, truest creativity.
>
> <div align="right">(Vygotsky, 2004/1930: 11)</div>

Vygotsky also suggests that play is a 'leading activity' - leading children on to the acquisition of new skills and/or knowledge and understanding. Play has been identified as a factor in the improvement of cognitive processes linked to creativity, such as problem-solving (Sylva, Bruner and Genova, 1976), and has been identified as a factor in the development of creative practice (Holmes and Geiger, 2002; Leiberman, 1977; Vandeburg, 1980; Wood and Attfield, 2005). Various studies have indicated that children's creativity is enhanced through play (Berretta and Privette, 1990; Dansky and Silverman, 1973; Howard Jones, Taylor and Sutton, 2002). Given the relation between creativity and play, the latter has been identified as a critical element in early years provision, with recent debates focusing on the extent to which play should be self-directed or shaped by practitioners (Wood, 2013).

Play has also been identified as an important factor in the provision of makerspaces that foster engagement. For example, the Ultimate Block Party Initiative was a coalition of scientists, community leaders and business that collaborated in the provision of events that promoted making and playful learning. Zosh, Fisher, Golinkoff and Hirsh-Pasek (2013) report on an event held in New York City, in 2010, which included 28 activities that spanned eight domains of play: adventure, construction, physical, creative, the arts, make-believe, technology, language play. The event attracted over 50,000 participants and was successful in fostering a playful approach to making. On a smaller scale, in a more recent study conducted by Whyte (2016) of makerspaces in an Ontario library, the researcher found that the first theme that emerged from a review of her data was play. The adults attending the makerspaces engaged in playful behaviours and they used terms such as '"play" or "play around with" to describe their interactions with the tools (Whyte, 2016: 4).

### 1.4.3 Social and Emotional Development

Early childhood educational provision places great emphasis on the importance of providing space and time for children's social and emotional development. Given the significance of the early years in terms of, as the US National Scientific Council on the Developing Child puts it, 'Establishing a level foundation for life' (2012), and the evidence for the relation between social and emotional development and academic success (Denham and Brown, 2012), it comes as little surprise that almost all early childhood curricula across the globe put emphasis on this aspect of development (Betram and Pascal, 2002). Therefore, early years practitioners foster values such as caring for others and expressing feelings.

As Hatch's (2013) emphasis on 'sharing' indicates, makerspaces offer such opportunities. Petrich and Bevan (2013: 53-4) argue that makerspaces foster solidarity with others, and David Gauntlett, in his book *Making is Connecting*, makes the point that, 'acts of creativity usually involve, at some point, a social dimension and connect us with other people' (2013: 2). Thus, makerspaces offer children the potential to develop their social and emotional capacities through such interactions.

### 1.4.4 Empowerment of the Child to be an Autonomous Learner

Early childhood pioneers such as Froebel (1899) and Montessori (1917/ 1965) argued that children learn when they make active choices about what they want to do, in stimulating environments. In the twentieth century, Piaget (1936/ 1953) and Vygotsky (1978) dominated the understanding of a constructivist approach to early learning, and whilst Vygotsky's work can be characterised as more sociocultural in nature, the two strands of work overlap:

> The two theories of leaning that have dominated thinking in the early years literature and in the professional education of teachers – the work of Piaget and Vygotsky – can both be interpreted as offering support for an active learning pedagogy, or at least drawing attention to features of the learning process that require active engagement with the environment and the people in it.
>
> (Stephen, Ellis, and Martlew, 2010: 317)

Influenced, therefore, by a long-established body of thought that emphasises the need for children to be able to lead their own learning, early childhood provision fosters independent learning and promotes the active engagement of learners. Similarly, a range of scholars point to the way in which makerspaces enable participants to become active learners who are self-directed (Halverson & Sheridan, 2014; Martinez, & Stager, 2013; Sheridan et al., 2014).

### 1.4.5 Makerspaces in Relation to Specific European ECE Movements/ Philosophies

There are a number of early childhood movements, philosophies and/ or traditions that relate to all or certain aspects of the makerspace movement. Three of the most widely-known in Europe are Montessori, Waldorf Steiner and Reggio Emilia. It will be of relevance to this literature review, therefore, to consider each of these in order to identify how far the principles of maker education are embedded within them.

The first Waldorf Steiner school was established in 1919, in Germany, by Rudolf Steiner, described by Edwards, who introduced his work to a North American audience as 'a maverick Austrian scientist and philosophical thinker' (2002: 3). Steiner characterised the early years as one of imitation, where children 'learn by empathy and doing' (Uhrmacher, 1995: 389). In Waldorf Steiner Kindergartens, the emphasis is on play, creativity, stories and music, and the aim is to develop a child who can make sense of the world holistically, uniting body and mind, and constructing an affinity with the natural world. Practical making activities, including building with wooden bricks, are important for developing an understanding of the physical properties of materials, and there is an emphasis on natural materials; digital technologies are seen as detracting from children's learning. However, whilst purporting to place the child at the centre of her or his learning, the movement has been viewed as one in which children's choices are tightly controlled within a very specific vision and approach, so that Wilson (2017: 2), for example, argues that 'the Waldorf philosophy has much in common with dominant US American ways of constructing childhood that reifies a Western, White, middle-class protected childhood as the most legitimate and healthy context of development'. Therefore, whilst certain aspects of the makerspace approach to learning might resonate with Waldorf-Steiner approaches, such as an emphasis on first-hand experiences with materials, its antipathy to technology suggests that nurseries and Kindergartens adopting this approach would not be keen to allow children to tinker and hack using non-natural materials.

Developed by Maria Montessori in Italy in 1907, the Montessori approach emphasises 'sensory input, regulation of movement, order, and freedom to choose activities and explore them deeply without interruption' (Edwards, 2002: 6). The focus is on developing individual children's potential and independence in learning, through constructivist principles. Children are taught within a three-year integrated age mix (3-6 in Kindergarten). A collection of carefully chosen objects and materials are used in the classroom to foster learning, including natural materials. However, whilst the Waldorf-Steiner approach projects an antipathy towards the use of digital technologies, this is not the case with Montessori settings, which take their lead from Montessori herself, who said that, 'Wherever possible mechanical contrivances are introduced for every detail of practical life, so that our children may be fitted to take part in a civilisation which is entirely based on machines (Montessori, 1948: 8). The American Montessori Society supports the use of

technology, but it advocates that it is used in ways which are seen to align with the Montessori philosophy (see Elkin, Sullivan and Bers, 2014 for an example of robotics teaching in a Montessori setting). Therefore, it can be argued that a makerspace approach would be valued by Montessori educators because of the emphasis on constructivist learning, problem-solving and logic, and creative design. Indeed, Hsu, Baldwin and Ching (2017: 1) argue that 'the maker movement is rooted in the works of Dewey, Piaget, and Montessori (Martinez and Stager, 2013), with their emphasis on active learning, constructivism, and a prepared environment'.

It is also the case that there is much within the Reggio Emilia approach that resonates with makerspace pedagogy. Loris Malaguzzi developed the Reggio Emilia system in northern Italy after the Second World War. Edwards argues that:

> Reggio Emilia is not a formal model like Waldrof and Montessori, with defined methods, teacher certification standards, and accreditation processes. Instead, educators in Reggio Emilia speak of their evolving "experience" and see themselves as a provocation and reference point, a way of engaging in dialogue starting from a strong and rich vision of the child.
>
> (Edwards, 2002: 6)

Underpinning Malaguzzi's philosophy was his belief in the 'hundred languages' of children, i.e. children have many different ways of expressing themselves, including through words, movements, art, music and so on. The emphasis is on experiential learning and artistic expression, and the approach involves children engaging in long-term projects in which they can experiment and play. Teachers (termed 'ateliers' - artists) facilitate children's learning through observing their practices and finding ways to support and extend their thinking and experiences, working alongside them to document their progress. The Reggio Emilia philosophy aligns well with a makerspace approach and, as in Montessori practice, technology is seen to have its place in a curriculum in which the emphasis is on knowledge construction using a range of appropriate tools for specific purposes.

Thus, it seems that the emphasis in makerspaces on experiential, constructivist approaches to learning in which young children are encouraged to experiment, take risks and lead their own learning has a long and well-established history in some European approaches to early childhood education. In addition, in many Nordic countries, making has been an important element of the early childhood and primary phases, with crafts such as woodworking, sewing and clay work being part of everyday practice, at least until recent years, when pressures related to a performance-orientated approach have led to a greater emphasis on the 'basics' in some areas (Ringsmouse and Kragh-Müller, 2017).

### 1.4.6 Makerspaces in Early Years Settings

Despite the emphasis in many early years traditions on creativity and making, few studies have explored the specific introduction of a makerspace approach in which tinkering, hacking and creating using a range of both digital and non-digital tools is fostered, leading to the integration of STEM with arts (STEAM) and humanities. This may be because the distinction between standard early years approaches and makerspaces is viewed as artificial, which can certainly be argued to be the case in relation to the Reggio Emilia approach. However, in many early years settings, it is not the case that children can choose to use a range of tools to create at will - they normally have to choose from among a defined set of resources chosen daily by nursery/ Kindergarten staff.

The work on embedding a makerspace approach within Kindergarten and first grade elementary classrooms has largely, to date, been undertaken by individuals or teams that already have established practices with regard to the use of digital technologies in early learning. Thestrup and colleagues (e.g. Thestrup & Robinson, 2016), as outlined in this review, have undertaken a range of work on experimentation and making within Danish Kindergartens, largely focusing on the use of innovative technologies, such as blue and green screens. Kumpalainen, in the Playful Learning Centre at the University of Helsinki, has developed a range of approaches to playful learning that draw from makerspace practices, these are now being taken up by the Helsinki education authority as a whole (Kumpulainen et al., 2017). Karen Wohlwend and Kylie Peppler (2015) have developed a

'playshop' model, in the USA, in which children can use a range of materials including e-textiles, conductive play-doh and film-making equipment to create playful and imaginative artefacts and stories. They describe a 'Squishy Circuits Design Playshop' that brings together learning across four quadrants: play, collaboration, new technologies and a content area in literature, arts or science (Wohlwend, Peppler & Keune, 2016). This work provides a strong platform for future developments in the field.

### 1.4.7 Conclusion

From this brief review, it is clear that the pedagogical principles that operate in early childhood settings across the globe resonate strongly with the approaches undertaken in makerspaces, which to date have more usually been attended by older children, young people and adults. This offers a strong rationale for the extension of the work on makerspaces into early years provision, and it means that early years practitioners might readily embrace the approaches and practices adopted in makerspaces, which will be a strand of enquiry in the MakEY project. Arguably, one way of fostering makerspaces within early years settings is to adopt a studio-based approach, resonating with the Reggio Emilia philosophy, but with greater attention paid to some of the more recent developments in digital fabrication in considering the tools and resources to be made available, and recognising the value of engaging staff who are skilled in these areas. How far this approach is possible within the context of the policy and resource constraints faced by many early years practitioners will be one line of inquiry within the project.

## 1.5 SECTION SUMMARY
*Jackie Marsh*

This section has outlined the history, significance and potential of makerspaces for education. These spaces offer much potential for young children. A recent NMC Horizon report suggests that makerspaces have 'the potential to empower young people to

become agents of change in their communities (Johnson et al., 2015). As they become increasingly popular, it is important to consider the ways in which different kinds of spaces and contexts shape particular experiences within makerspaces. Peppler, Halverson and Kafai (2016) make a convincing case for considering the ways in which such spaces break down barriers between informal and formal learning, whilst recognising that it is also the case that makerspaces are instantiated in different ways in relation to the various contexts in which they appear. In the following section, the ways in which makerspaces have been experienced across a range of formal and informal contexts, including libraries, museums and schools, are considered.

# SECTION TWO

## MAKERSPACES IN INFORMAL
## AND FORMAL LEARNING SPACES

In this section, the ways in which makerspaces are organised and delivered in different spaces are considered. It is recognised that enforcing strict boundaries between formal and informal learning is impractical, given the complexities involved in categorising both learning *and* spaces (Sefton-Green, 2013), but given the different histories of makerspaces in settings such as schools, libraries and museums, it is of value to consider each of these contexts separately.

### 2.1 COMMUNITY MAKERSPACES AND MAKER FAIRES
*Jackie Marsh*

In Section 1.2 of this literature review, George Marusteru provided a history of the emergence of makerspaces within the community. These are generally open access spaces that enable the general public to engage in making activities. The nature of spaces can differ in relation to how they operate and their general aims, with some sites operating for profit whilst others are collective enterprises. Given the challenge of the conceptualisation of the notion of 'community' (Blackshaw, 2010), there is no intention here to signal that there is a standard model for a community makerspace that should exist; rather, we need to acknowledge that there is a wide variety of spaces that operate according to their own sets of principles. Whilst some attempt to be collectives, with egalitarian and inclusive practices, others have, according to Cunningham (2017), bought into neo-liberal discourses of the creative economy through sponsorship or a focus on entrepreneurship, becoming part of the process of the de-politicisation of urban spaces.

Whilst a number of claims have been made about how makerspaces can promote democratic participation in society (Anderson, 2012), the reality is rather different. The majority of makerspaces are located in urban spaces, which immediately excludes many people living in rural communities from participating. Further, Alper (2013: 1) reported on a US survey that found that '8 in 10 makers are male, their median household income is $106,000, and 80% have a post- graduate education', which indicates a need to ensure that makerspaces reach out to all communities. These issues are considered in Section 4 of this literature review.

The engagement of young children in community makerspaces is minimal, as this age group is not the target demographic of such spaces. There is, however, some interest from elements of the makerspace community in reaching out to families and children, which has led to the development, for example, of the Junior Lab in Berlin, hosted by the Berlin Fab Lab. It is expected that interest in this area will continue to rise, and such spaces will offer different types of experiences than the makerspace opportunities currently available to children, such as those in schools, libraries and museums. One advantage of attending makerspace sessions in open lab spaces is that they normally provide access to larger pieces of equipment that may not be available in a pop-up makerspace, and these enable children to interact with specialists in the area. One such opportunity for these types of experiences currently exists in the form of Maker Faires.

In 2006, in the US, the first Maker Faire was held, 'dedicated to the celebration of the 'maker mindset'' (Tocchetti, 2012:1). There are now regular Maker Faires held across the world, and these provide spaces in which makers can share their creations, as well as spaces in which maker events and workshops are held. The first Maker Faire was developed in the San Francisco Bay Area and its creator, Dale Dougherty, who also launched MAKE magazine, points out that the main thrust of the Faires is communication:

> At the Faire, a maker could put an object they created up on a table and have people ask them about it. Having that kind of conversation with a range of people is the essence of the magazine, of the Faires–and perhaps of the whole movement.

> (Dougherty, 2012: 11)

The first Maker Faire had 100 exhibitors and 22,000 people attended; in 2016, over 1.4 million people attended Maker Faires [7]. It is expected that there will be Maker Faires in 38 countries in 2017, including in Australia, Canada, China, Europe, India, Italy, Japan, Norway, Singapore, Turkey and the USA.

One of the key benefits of Maker Faires is that they enable makers to develop links with like-minded others, in what Gee (2005) terms an 'affinity space'. Maker Faires are not the only means by which makers form communities and networks, of course. Hobson Foster, Lande and Jordan (2014) interviewed 21 exhibitors at a Maker Faire in the US and noted that:

> The majority of participants reported that they are steadily involved in formally organized Maker activities beyond the Maker Faire. Examples of organizations that the Makers are involved in include annual Maker events such as Burning Man, specialty technical groups and hobbyist/hack clubs, outreach organizations and competitions such as FIRST Robotics, and organizations that celebrate making such as Makerzine and Instructables.
>
> (Hobson Foster, Lande & Jordan, 2014: 5)

Maker Faires enable a collective celebration of making and provide valuable opportunities to learn from others. In addition to having 'show and tell' sessions, Maker Faires also enable hands-on experimentation, workshops in which specific skills are taught and interactive exhibitions of new technologies, such as robots and 3D printers. Over the years, there has been a growing interest in the fairs from families. Indeed, Maker Faires now advertise themselves as 'family friendly', although the inter-generational nature of the exchange is emphasised, rather than a specific focus on children. It is to be expected, as Make Faires grow in popularity, that a younger audience will demand activities that meet their needs, and the response of the maker community in this respect will be of interest to early childhood researchers in the years ahead.

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[7] http://makerfaire.com/media-center/#fast-facts

## 2.2 MAKERSPACES IN FORMAL EDUCATION

*Skúlína Hlíf Kjartansdóttir, Svava Pétursdóttir, Gísli Thorsteinsson and Kristín Dýrfjörð*

During our literature review we searched different reference libraries, such as ERIC, Ebsco host teacher reference centre and Proquest, using the terms makerspace, fab lab, hackerspaces and tinkering in a string with the terms education, schools, formal education, primary and early years. We read through 34 abstracts from papers and books, including exemplars of makerspaces in formal education. Upon closer scrutiny, the literature did not provide many examples of actual making projects within formal education but rather in libraries and in relation to after-school activities. The main focus of the literature was on STEM or STEAM projects, but with rather loose connections in terms of the makerspace context. However, there was a strong understanding of the possibilities of enhancing learning through making and the value of a maker culture in support of formal education.

### 2.2.1 Societal Changes and Making

Every few decades or centuries, a new set of skills and intellectual activities become imperative for work and citizenship. They often democratise tasks and activities that previously were only carried out by experts (Blikstein, 2013). The impact of computerisation and computer programming in society, in this respect, is felt not only at work and in the home, but also increasingly in schools. Therefore, computers and affordances for digital fabrication have begun to affect conventional education (Gerschenfeld, 2012).

Many early educationalists, like Dewey, insisted on the idea that education should be experimental and connected to real-world objects and experiences (Dewey, 1902). Pestalozzi developed the idea that children are inherently creative and express themselves best through action. He felt that making lies at the centre of all learning (Thane, 1914[8]). Froebel converted Pestalozzi's theories into practice with the development of the first "Kindergarten" in 1837. In this school, the predominant idea was

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[8] Thane, L. (1914). Om Slöjd. Aands og haandsudviklingen I skolen. Copenhagen: Pios Boghandel.

that activity precedes thinking, education must begin with making activities, students could discover, arrange, invent and control. Illich (1970) and Freire (1974) criticised the decontextualization of curricula. Freire introduced the idea of a 'culturally meaningful curriculum construction' in which designers are inspired by their local culture to create 'generative themes' with other members of that culture (Blikstein, 2013). Meaningful activities, at either personal or community levels, can lead to design solutions that educate and empower the learner. Papert's constructionism emphasises that construction of knowledge is well supported when learners build, make and publicly share objects (Papert et al. 1991). Papert advocates the use of technology in schools as emancipatory equipment that can provide learners with powerful construction tools for making, rather than being a way to optimise traditional education.

## 2.2.2 The Makerspace Goes to School

Theoretical foundations of 'making' and digital fabrication in schools refer to experiential education, constructionism and critical pedagogy (Blikstein, 2013). The Maker Movement highlights the pedagogical value of problem-finding, problem-solving and the power of social learning through sharing and collaborative work (Smith and Smith, 2016). Teachers too have been encouraged to focus on the creative artistry of students as opposed to their technical expertise (Robbins and Smith, 2016). Makerspace activities can encourage schools to use methods for teaching students to thrive in a new economy and environmental circumstances where creativity is important (Craddock, 2015). It can, moreover, teach them about community service, developing leadership and problem-solving skills (Sheridan et al., 2014).

As makerspaces have begun to move into classrooms and school libraries, there has been a growing need for teachers' professional development. Maker leaders have recommended that such training be applied in workshops with the goal of encouraging more maker-oriented practices in formal learning contexts (Oliver, 2016). Teachers have to be prepared to implement appropriate teaching methods for a class by using complex technologies, solving technical problems and adapting to new circumstances (Hira et al., 2014; Demetriadis et al., 2003; Hennessey and Deaney, 2004).

To develop teachers' capabilities to teach design literacy to children in the makerspace context, their mindset has to be developed. A strong focus on design thinking and complex problem-solving during teachers' professional development can improve their capabilities to manage students' making processes in digital fabrication contexts. They need to build a repertoire of working with miscellaneous materials, advanced technical equipment and software applications and be able to devise new educational practices (Oliver, 2016). Research has identified the importance of teachers, in this context, as playing the roles of both traditional instructor and facilitator and adapting to the role of facilitator rather than instructor, echoing a social constructivist approach and giving students flexibility for ideation (Bauersfeld, 1995; Gunnarsdottir, 2001; Jónsdóttir and Gunnarsdóttir, 2017; Thorsteinsson, 2013). At the same time, they have to provide students with basic training in using the technology, keep them motivated and be able to shift the focus from conventional learning outcomes to reflective and transformative educational practices (Hjorth et al., 2016)

It is noteworthy in this context that conditions for makerspaces in preschools, primary and secondary schools vary considerably according to cultural contexts and national educational systems. Blikstein has commented on the lack of spaces for engineering and invention in schools early on in the development of the maker movement in the USA (Blikstein, 2013). In many countries in Europe, where there is still a strong emphasis on crafts, arts and vocational education in schools, workshops exist that can be redesigned to include digital fabrication facilities. Where this is the case, such as in Scandinavia, there are also strong traditions of making and curricular structures to align with, when makerspaces are set up in schools, or when reinvention of the national core curriculum is put on the agenda.

The evolution of computer software applications to make programming easier for students has been supportivec for the makerspace movement. The evolution of user-friendly software applications for CAD-CAM has also made computer-aided manufacturing easier than before. New ideas and tools for digital fabrication and 'making' have demanded new forms of expression and empowerment for students. For example, programming tools, like

Scratch (Resnick et al., 2009), that make programming easier to learn at school, have created a novel basis for self-expression and literacy.

The maker movement (Blikstein and Kranich, 2013) and the maker culture (Cohen et al., 2016) have enabled individuals to work together creatively in order to participate in the evolution of society by using makerspaces around the world (Halverson and Sheridan, 2014). Martin (2015:30) describes three elements that are necessary to understand the promise of the maker movement for education: 1) digital tools, including rapid prototyping tools and low-cost microcontroller platforms; 2) community infrastructure, including online resources and in-persons spaces and events; and 3) a maker mindset, aesthetic principles and habits of mind that are prominent within the community. Maslyk (2016) claims that STEAM/ Makers education can be seen as running counter to the trends of accountability education and managing by numbers. She states that 'the notion of citizens as makers, not consumers, connects to the mindset that is growing the maker movement and STEAM education' (p.4).

### 2.2.3 Makerspaces in Pre-schools

Pre-school is defined in the context of the makerspace movement as an early childhood programme for children under the age of six. Pre-school education has a long-standing connection to education based on playful learning and the idea of learning by doing. There is also emphasis on the education value of experience through the senses and acting accordingly (see Section 1.4, in this review). There has been a strong emphasis, in the US, on connecting STEAM and early childhood education (Sousa and Pielecki, 2013). One way to go is through teachers' professional development. The makerspace movement will probably also focus on working inside early childhood classrooms. Wohlwend et al. (2016) see the 'Maker Movement as an opportunity to infuse technology into early childhood curricula through teachers' expertise in familiar staples of early childhood education: dramatic play and exploratory design with art materials' (p. 85). According to their research, pretend play attaches new meanings through playing with makers' materials and, what is most important, when combined, the shared effects of play and design are strengthened.

As discussed previously, the Reggio Emilia pedagogy has been used to underpin an understanding of the possibilities that exist in this context. Loris Malaguzzi actually wrote about the pedagogical role of computers in pre-schools in the 1980s (1988). Filippini has also commented on the role of early childhood teachers in Reggio Emilia preschools:

> The teacher must learn how to listen, how to see and understand the children's behaviour in order to measure his own procedure. Only in this way will the teacher be able to create situations where real learning takes place; situations where the adult and the child create new knowledge together. This is about creating knowledge, not transmitting it.
>
> (Filippini, 1992: 145)

To prepare preschool teachers via professional development for undertaking makerspace activities with young students is important in terms of taking on board multiple roles and enabling their pedagogical understanding in this context. Maslyk (2016) claims that building expertise among teachers is a key but time-consuming factor. She also mentions the importance of teachers adopting suitable mindsets for makerspace activities, what she calls a maker mindset. She claims that developing a maker mindset entails teachers and students building qualities of perseverance and persistence in the face of challenges.

Educators in the Slovenian preschool Vodmat (Janota, 2016) have created a model for helping early childhood teachers to develop a way of working with new ideas in pre-school. The model, called the Inductive Model, is presented in five steps:

1. Encouraging personal experience. Art can be a most effective medium to 'open the senses' and increase one's sensitivity to a certain topic.
2. Focusing on obtaining knowledge about a certain topic–familiarisation and producing meaning–whereby children look for information through books, pictures, music and so on.
3. Dialogue–children use acquired knowledge, shared experiences and ideas and get feedback on their explorations, themselves, their view of the world, and so on.
4. Creativity. Children report the content of a project through an art experience, artists join in the pedagogical process and help to establish dialogue by engaging

children in working with materials in creative ways that materialize experiences and emotions.

5. Social engagement—claiming a space and the right to make a statement and exhibit their views, experiences and ideas, and to participate in society. (Janota, 2016)

Vodmat pre-schools have gained many awards for their work and are seen as a good example of the Inductive Pre-school Model in action. It could, therefore, be of interest for pre-schools that are planning makerspaces to consider the Slovenian model as a beneficial pedagogy for pre-school teachers who want to guide students when working with materials in a creative manner influenced by their experiences and emotions. It also refers to the makerspace ideology in terms of students' participation in society, via their ideation and making.

### 2.2.4  Makerspaces in Primary/Secondary Schools

Separate developments and projects have created the impetus for digital fabrication and makerspaces in schools and produced affordances for programming, robotics and digital fabrication. Programming languages such as Logo (Logo Foundation, 2017), the first programming language designed for children, and various open digital software programs have fuelled this development. The Massachusetts Institute of Technology (MIT) and its interdisciplinary Media Lab (MIT media lab, 2017) fostered many of these projects in the early stages, as well the FabFoundation (FabFoundation, 2017). The FabFoundation now runs the FabLabs network in 40 countries, with approximately 200 FabLabs that train teachers in an open, creative community.

Maker programmes in primary and secondary schools are now being established worldwide by different organisations. The FabLab@School project, now FabLearn (FabLearn, 2017), was developed at Stanford University (USA) and disseminates best practices, ideas and resources internationally to support educators, researchers and policymakers seeking to introduce 'making' into informal and formal education. In Europe,

various software/ hardware projects, such as Arduino, Rasberry Pi and BBC Microbits, are adding variety to the resources available for making and digital fabrication in schools.

FUSE studio (FUSE, 2017) is a set of challenges, interest-driven learning experiences developed by a team at the School of Education and Social Policy at Northwestern University (USA), that engages pre-teens and teens in STEAM topics, while fostering 21st century skills. FUSE is currently being used in Finland as part of the preparation a new Finnish curriculum for primary and secondary schools. Research addressing teachers' agency in making sense of an educational change effort within two Finnish schools reveals four sets of agentive orientation: practical-evaluative, reproductive, critical-projective and creative-projective (Rajala and Kumpulainen, 2017). It is suggested that these agentic orientations and their temporal features unpack the dynamic processes of how teachers manage educational reforms to address their personal and local needs. Successful educational change in the school community requires teachers to reconcile and negotiate a joint understanding between different and possibly contradictory orientations. The authors conclude that for sustained educational change to take place, collective sense-making is essential.

Research indicates that introducing digital fabrication in education is not a straightforward process, but design thinking can benefit students at the primary and secondary levels, as an integrated part of the educational setup (Smith et al., 2015) where failure, iterative processes and continuous reflection are encouraged. There seems to be a general consensus that making and tinkering projects open up possibilities for weaving together informal and formal education (Rees et al., 2015); design thinking is seen as effective for empowering minority groups (Rees et al., 2015) and opening up STEM to multicultural groups and women (Norris, 2014). Some interesting research articles exist on the practice of makerspaces in schools, such as: 'Robo/graphy: Using practical arts-based robots to transform classrooms into makerspaces' (Robbins and Smith, 2016) and 'Creating a prosthetic hand: 3D printers innovate and inspire a maker movement' (Cook et al., 2015).

One aspect of the maker movement is that its participants share their work openly, also curricular resources (Blikstein et al., 2016) that benefit teachers who want to incorporate making into their agenda at schools. These resources need to be adapted to their local

situation and circumstances, with teachers often juggling different philosophies of education, inertia to risk and limited resources. Resulting multiple models of implementation, curriculum constructions and assessment methods appear to be developing and can encourage teachers in their endeavours to introduce making in their teaching.

Student- or teacher-driven learning and assessment does not always sit easily with a standardised curriculum and testing or current assumptions about college preparation and career readiness (Flores, 2016). Experiential learning and student-driven projects can be more challenging to assess than standardised learning content and therefore need an alternative evaluation model. Recent attempts have been made to create and test a new assessment instrument for exploration and fabrication technologies (EFTs) literacy (Blikstein et al., 2017). They suggest that the 'survey instrument tracks student confidence in EFT skills and assesses how that confidence relates to actual task performance' (Blikstein et al., 2017:149). It was tested in five schools in the USA and the analysis showed a 'marked difference between students' confidence in EFT and their performance in it' (ibid:167). This gap between confidence and performance may reflect the difference between knowing technology and being able to use it effectively. The research concludes that 'the EFT instrument captures a new and distinct set of technology literacies that arise within fabrication settings and are independent of both general computing and digital content production skills' (Blikstein et al., 2017:168).

Christensen, Hjorth, Iversen & Blikstein (2016) argue that design literacy is a new literacy that is particularly relevant for assessing learning in makerspaces. It sits under the new literacy umbrella (Coiro et al., 2014) with other types of literacies (21st century literacy, Internet literacy, digital literacy, multimedia literacy, technological literacy, information literacy, ICT literacy, visual design literacy, multimodal literacy) that are used by different research discourses. This group of researchers has developed the Design Literacy (DeL) assessment tool. The survey tool has 'three levels: (1) design of qualitative, wicked survey questions, (2) a coding scheme for assessing aspects of a designerly stance towards enquiry, and (3) an example of analysis and quantitative data validation for transparency and guidance' (Christensen et al, 2016:127). The tools are focused on 'students' stances towards inquiry when challenged with a survey question that is wicked and embodies the

following five aspects: (1) societal challenges, (2) dilemmas, (3) ethical issues, (4) multiple stakeholders, (5) unfamiliar domains' (ibid:129). The aim of the tool is to capture and assess pupils' design literacy skills in makerspaces. The team report that:

> …the DeL tool has been tested in situ on students in K-12 schools and university students, but we do not yet have any data to support use of the DeL tool for younger children….the DeL tool also has to be adjusted to sociocultural contexts.This includes considering aspects related to demographic, geographic, age-related and general cultural aspects.
>
> (Christensen et al, 2016:143-144)

The authors state that they intend to make the DeL tool freely available online for K-12 educators.

So far, research on makerspaces and making has mostly focused on the learning aspect, the activity, design and design literacy, as well as on how learning in makerspaces can be evaluated. As Litts remarks in her PhD thesis (2015), less research effort has been observed in relation to the social side of making and on the community of makers, providing us with an understanding of how individual identities are nested within community ethos and the role the community plays in learning through making.

Makerspaces might be diverse in nature across schools, but in general they will involve a room with resources to work on technical assignments, supported by a maker community. They can become a place for either formal or informal learning and enrich the school curriculum in a cross-curricular manner or inside certain subject areas (Oliver, 2016). Hundreds of schools are starting fablabs and makerspaces and thousands have robotics programmes (Blikstein et al., 2016). Scratch and NetLogo are currently used by millions of children and adults in fifty languages. This clearly demonstrates the interest and potential that educators attach to learning through making. However, there is, as yet, only a limited set of studies relating to the use of makerspaces in early years settings, and this is a significant gap in the literature to date.

## 2.3  MAKERSPACES IN LIBRARIES

*Margrét Elísabet Ólafsdóttir*

Findings show that the interest in makerspaces in libraries has been growing over the last decade, particularly in the USA where makerspaces can be found in public, school and academic libraries. The choice of the library as a physical space for a makerspace is based on the historical role of the library as a shared space with shared resources. The new technologies serve as a catalyst for a new model of community resource, i.e. the makerspace (Britton, 2012; Harris & Cooper, 2015).

A large part of the literature on the subject is about specific cases and the experiences of librarians running makerspaces in school libraries. A common thread is that the makerspace provides an answer to the need of the library to evolve and adapt by meeting the needs of their communities through the provision of access to tools unavailable elsewhere. (Britton, 2012). The makerspace has been seen as enabling librarians to better serve their communities and extend the libraries' purpose by offering solutions to current requests (Harris & Cooper, 2015), changing libraries into learning commons (Kompar, 2015).

Learning commons were a driving force behind a two-year programme of re-imagining the library, which included setting up makerspaces in school libraries (Kompar, 2015). As Kompar (2015, n.p.) notes:

> A learning commons is a philosophical and paradigm shift that incorporates and supports school- and district-wide initiatives, such as the implementation of digital learning….inclusive of a rich integrated, digital and media literacy curriculum, 24/7 access to collaborative media engaging the users in participatory digital spaces; and flexible user-centred, creative physical spaces.The transformation of the traditional school library into learning commons provides relevant resources in a variety of formats and expertise on incorporating research/ information fluency and media and digital literacy.
>
> (Kompar, 2015)

The experience of transforming the library space into a common space offering collaborative activities has been successful as it has turned setbacks and losses into positive results, with increases in the circulation of books and collaborative instruction with teachers (Kompar, 2015)

Smay and Walker (2015) suggest that the experience gained from setting up a makerspace in a school library shows that it may intrigue students who want to explore unfamiliar technology The makerspace can also open up new collaborations between staff. The challenge of the makerspace within a school library has been to find out how to support the curricula of all age groups and embed them into the makerspace. Smay & Walker (2015) argue that experience has shown that the makerspace can offer a blended model of support for all age groups by being a resource for the independent student, and a support to classrooms, offering 'different ways for students to demonstrate their knowledge through different formats or media' (ibid:n.p,). They have also helped teachers design their own teaching models and tools

Makerspaces have offered possibilities for all age groups to develop projects according to their needs, with adapted methods to capture their interest and keep it. Choosing the library as a place for the makerspace has encouraged collaborations between teachers across curricula and subjects. Instead of being confined to their classrooms or specific labs, teachers meet other teachers in school-library based makerspaces. Another benefit found is that assignments set in makerspaces engage students in work that challenges them to be curious and open-minded. (Smay & Walker, 2015). It is generally held that the makerspace fosters creativity, innovation and exploration by helping students to acquire new skills, and by offering support and expertise (Smay & Walker, 2015; Harris & Cooper, 2015). This type of activity has been seen as a catalyst for a mindset that should help students to develop a positive approach to life-long learning (Smay & Walker, 2015).

The number of makerspaces in libraries has increased in recent years, but they still need to justify their existence. Libraries have learned from running makerspaces that it takes time and patience to find out how to use the tools, especially 3D printers, but also other equipment. Maintenance and fixing equipment also takes time (Harris & Cooper, 2015). Thus, libraries are challenged to sustain their makerspaces by articulating their vision for

the future and their purpose in having a makerspace. In a review of public discourse related to makerspaces in libraries, undertaken by analysing relevant publications, including journal articles and blogs, Willett (2016) identifies a series of tensions and contradictions in the literature. She argues that:

> …polarized accounts present in the data set position formal educational content, styles, and pedagogies in negative ways and oversimplify the distinctions between formal and informal learning settings. This raises questions about how makerspaces engage in a range of styles of teaching and learning and who might benefit or be excluded from different teaching styles. As the makerspace movement in public libraries progresses, these tensions and questions potentially offer space for dialogue about aims, purposes, and best practices in relation to making and makers.
>
> (Willett, 2016:326)

In the years ahead, it will be important for research on makerspaces in libraries to address some of these issues, in addition to identifying the way in which such spaces can be maintained in the light of significant cuts in public funding for libraries in many countries.

## 2.4  MAKERSPACES IN MUSEUMS

*Jackie Marsh*

Museums were among the first institutions to embrace the makerspace movement, particularly science-focused museums. The National Science Foundation in the USA has funded a number of maker initiatives in museums, including the Tinkering Studio at the Exploratorium in San Francisco, and the New York Hall of Science. In a review of research conducted in this area to date, it is clear that these science-based museums have been the focus for a larger number of studies than other types of museums (e.g. Bevan et al, 2015; Gutwill, Hido and Sindorf, 2015; Petrich, Wilkinson and Bevan, 2013; Vossoughi and Bevan, 2014)

One of the major foci for studies of engagement in STEM-related activities in museums has been learning, and, in particular, learning that is based on constructivism (Piaget, 1936) and constructionist (Paper; 1980; 1993) models of learning. Some of this work has led to the development of models for identifying the learning that takes place in these environments. For example, Bevan et al (2015), in an analysis of participants' activities in the Exploratorium's studio, observed 50 individuals and groups, which led to the refinement of the 'Tinkering Learning Dimensions Framework', first developed in 2013 (Petrich, Wilkinson and Bevan, 2013) to identify the kinds of learning that took place. The team identified the following dimensions of learning as being key in the Tinkering studio: engagement; initiative and intentionality; social scaffolding and development of understanding.

There have been fewer studies of makerspaces in other types of museums. The Institute of Museums and Library Services (IMLS) has also sponsored makerspaces in museums in the USA, but with a broader focus than STEM. They have invested over $10,000,000 in making in museums and libraries since 2011and report that:

> History museums like Conner Prairie in Indiana and the Museum of History and Industry in Seattle are connecting their history content with STEM topics through makerspaces focusing on crafts, industry, and innovation. The California Indian Museum and Cultural Center is combining its historical lens with maker practices to focus on STEM topics incorporating Native and Western perspectives. In the

children's museum sector, experiences such as MakeShop at the Children's Museum of Pittsburgh; Young Makers at the Hands On Children's Museum in Olympia, Washington; and the Prop Shop at the Winston-Salem Children's Museum, fuse old and new technologies, storytelling, and STEM into safe and exciting spaces for tinkering and learning.[9]

In this summary of IMLS-supported initiatives, it can be seen that STEM is not the sole focus of this work. However, there have been few research studies conducted in makerspaces in museums that are not science focused. An exception is the work of Oates (2015), who conducted a study in the Maker Lounge at the Peabody Essex Museum (PEM), a museum that focuses on art and culture. She observed 25 participants in the makerspace and found that users engaged in a range of self-directed activities in which there was evidence of learning similar to the patterns found in STEM-oriented museums.

It is of little surprise that learning is similar in nature across makerspaces in different types of museums, given the nature of the activities that are undertaken within them. Indeed, there is evidence that learning in museum spaces shares many of the characteristics that are apparent in other kinds of makerspaces. Sheridan et al. (2014) and Litts (2015) report on studies which examined makerspaces in three different types of institution: in a community space, a library, and the Pittsburgh Children's Museum's Makeshop. The makerspaces all provided opportunities for unstructured, open learning, but the museum makerspace was different to the others in that it did not offer opportunities for long-term engagement in projects. Litts suggests that this may be because:

> …Makeshop appeals to an international audience and is bounded by admission costs and specific 'open' hours of the Museum. With a steady flow of new people day-to-day, the space is designed to support shorter spans of engagement and does not lend itself well to people leaving projects to return to later.

(Litts, 2015:104)

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[9] https://www.imls.gov/sites/default/files/publications/documents/makerspacestalkingpointsfinal.pdf

The majority of research on makerpsaces in museums has focused on older children, young people and adults. An exception to this is Brahms and Crowley's (2016) study of the Makeshop in Pittsburgh, also a site in the Sheridan et al. (2014) and Litts (2015) studies reported on above. Brahms and Crowley outline a case study of a four-year-old boy, Jake, who regularly visited the Makeshop. On his first visit, he worked with one of the facilitators to build a life-size model of a lawn-mower from wood, and then over his next visits, was skilfully guided in the making of a number of objects, all of which orginated in his everyday experiences outside of the museum. Brahms and Crowley (2016) indicate the need for museums to move beyond a model in which the visitor experience is geared around a single visit, and to, instead, consider engagement over time, an issue which also emerged in Litts' study of the Makeshop.

Across many studies of making in museums, the role of the facilitator is identified as being key. McCubbins (2016) used a standard tool for assessing engagement in museums, the Visitor Based Framework, to examine the responses of participants to a makerspace set up in a children's museum. It was identified that 'breakthrough engagement' (defined as engagement that involves participants linking learning to past experiences, making comparisons, testing variables etc.), was no greater than such engagement in non-makerspace exhibits at museums. However, it was found that where breakthrough engagement occurred, the knowledge and support of facilitators was key, along with parents' dialogue and children's interest in the activity.

From this brief review of the literature pertaining to the use of makerspaces in museums, it would seem that a key gap in the literature is the value and use of makerspaces in these venues for children aged under eight. Beyond the handful of studies focused on the Pittsburgh Children's Museum's Makeshop, there is little work that has studied in detail the values and outcomes of provision for this age group. In addition, there needs to be more attention paid to the different kinds of experiences and learning that take place in museums that have different foci. There has been an emphasis in research on makerspaces in STEM-focused museums, when other types of museums are increasingly offering making opportunities.

Finally, most of the research on makerspaces in museums has been conducted outside of Europe. There is a need to develop tools and resources which can support European museums' aspirations in this area. A well-established partnership between the Children's Museum of Pittsburgh and the IMLS has led to the Making + Learning project[10] being developed, which provides a range of resources and tools for museums and libraries who wish to develop makerspaces, including a framework to support learning[11] and an open-access MOOC[12] (Wardrip, Brahms, Reich, & Carrigan, 2016). In the years ahead, it will be of value for European museums and libraries to develop similar frameworks and resources that can inform their work.

## 2.5 MAKERSPACES IN AFTER-SCHOOL CLUBS

*Kjetil Sandvik*

This section must be considered as a work-in-progress: a first scan of the existing literature. A more thorough literature review needs to be conducted, and when doing so it should also focus on academic work in languages other than English: a search for 'after-school clubs' primarily finds publications from the US. An extended search for academic work related to 'after-school activities and programs' would also benefit from discussing what is understood as 'after-school': is it a continuation of the school day - particular spaces for other types of learning activities, e.g. in the form of making and tinkering but still in designed formalised learning processes, or do we understand it as being more along the lines of 'out-of-school', not just implying a change of locality from classroom to workshop facilities etc., but also a break from school: 'off-school' with a focus on self-organised activities? Whereas the first understanding of 'after-school' is prevalent in the US material (focusing on STEM and how makerspaces enable and empower learners to create, e.g. equity), in these particular educational efforts, the latter is hardly present, even though some work criticises the emphasis on formal learning goals and objectives and

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[10] https://makingandlearning.squarespace.com

[11] https://makingandlearning.squarespace.com/s/MakerspacesPub_v15.pdf

[12] http://p2pu.github.io/makingandlearning/

point to the fact that making also has more informal and playful features to it; others focus on the identity-making and communal aspects of makerspaces. For example, in a research paper on how and why youths engage in making in an after-school, youth-focused, community-based makerspace programme, "Making 4 Change", Barton, Tan, and Greenberg (2016) analyse four examples of how youth appropriate and repurpose the process of making. Their analysis unpacks how the programme attempts to value and negotiate youths' ways of making from an equity-oriented perspective.

Not much literature can be found when searching for academic work specifically on 'after-school clubs'. However, broadening the concept to 'after-school programmes' produces quite a few hits. The main bulk of academic work is typically based on (US) case studies and either looking at after-school makerspaces in connection to formalised learning programmes (within the K-12 framework) or at out-of-school settings with less focus on formalised learning and more focus on self-organised activities, communities of interest etc. In their report, Bevan et al. (2016) examine how after-school educators at four different organisations in the US have integrated making into their programmes in order to engage participants more deeply in STEM concepts, phenomena and practices. The report demonstrates how these programmes 'build on key characteristics of Making and Tinkering that have been extensively documented in the research literature' (Peppler et al., 2016; Resnick & Rosenbaum, 2013; Dixon & Martin, 2014):

- It exercises students' creative and improvisational problem-solving abilities;
- It builds students' agency, persistence and self-efficacy;
- It helps students to deepen and complexity their ideas and understanding. (Bevan et al., 2016: 2)

A substantial review of this type that categorises literature within this field can be found in Vossoughi and Bevan (2014: 5), who divide literature in the context of out-of-school-time STEM into three categories: a) making as entrepreneurship and/or community creativity; b) making as STEM pipeline and workforce development, and c) making as enquiry-based educative practice. The review points to the fact that the majority of work published in this field falls in the third category.

Martin (2015) argues that even though:

> The Maker Movement is a community of hobbyists, tinkerers, engineers, hackers, and artists who creatively design and build projects for both playful and useful end, there is growing interest among educators in bringing making into K-12 education to enhance opportunities to engage in the practices of engineering, specifically, and STEM more broadly.

<div align="center">(Martin, 2015: 31).</div>

He points to three elements of the Maker Movement that are crucial to promise for education: '1) digital tools, including rapid prototyping tools and low-cost microcontroller platforms, that characterize many making projects; 2) community infrastructure, including online resources and in-person spaces and events; and 3) the maker mindset, aesthetic principles, and habits of mind that are commonplace within the community' (ibid.).

Based on a PhD research programme, 'Learning in the Making', Litts (2015:7) describes makerspaces as a third place that exists between work/school and home, one 'where people meet informally and which offers people a unique and meaningful sense of worth'. Similarly, Lee, King, and Cain (2015) define makerspaces as being a self-identified 'third space' where people can gather informally to engage in digital fabrication practices and produce digital or digitally-enhanced artefacts. As indicated in Section 2.4, Litts specifically focuses on three youth makerspaces – museum, afterschool, and mobile/library – and analyses how young makers learn from making in those settings (Litts, 2015: 1), comparing the constraints and strengths of each makerspace and analysing how young makers approach and complete activities in those makerspaces: 'learning happens when one 'makes' rather than 'gets' both knowledge and artifacts' (Litts, 2015: 18). The empowering learning potential of participatory co-creativity inherent in makerspaces (in processes of making and tinkering) echoes former pedagogical philosophies. As argued by Resnick and Rosenbaum (2013):

> …the ideas and practices of the Maker Movement resonate with a long tradition in the field of education – from John Dewey's progressivism to Seymour Papert's constructionism – that encourages a project-based, experiential approach to learning. This approach is somewhat out of favor in many of today's education

systems, with their strong emphasis on content delivery and quantitative assessment. But the enthusiasm surrounding the Maker Movement provides a new opportunity for reinvigorating and revalidating the progressive-constructionist tradition in education.

(Resnick and Rosenbaum, 2013: 163).

This also relates to Gauntlett's reasoning concerning the educational role of making and doing contrasting with the 'sit back and be told' culture of Western educational systems of schooling and teaching (Gauntlett 2011). As Gauntlett points out, the DIY and making culture connected to the new forms of media use comes into serious conflict with the formal learning approaches in current educational systems. As Reese et al. (2015) have it, makerspaces have the potential for expanding educational programmes and methods for learning towards multimodal, flipped, entrepreneurial learning methods and practices.

Dixon and Martin (2013) caution against 'a reductive treatment of making as a set of component knowledge and skills' and argue that 'efforts to tie making more narrowly to STEM outcomes or to assume uniform outcomes in any particular area of learning may limit the openness of maker definitions, leave less room for exploration and personalization, and erode the value youth see in participation' (p.3). Based on their interviews with young makers, Martin and Dixon advocate 'a more holistic, youth-centered view of the role and value of making as an educative experience' (p.1). This may be seen in relation to the Scandinavian countries, where after-school settings such as youth clubs [ungdomsklubber, fritidsklubber] - publicly funded institutions (often located in specific parts of schools or as extensions of daycare institutions) - have traditionally been 'off-school' spaces without outspoken and formal learning goals. They have been spaces - equipped as what we today call makerspaces (workshop facilities for woodwork, mechanics (e.g. motorcycles) and music and media production (the latter dating back to the introduction of video cameras and editing systems in the early 1980s) - for self-organised maker activities. An important feature in the Scandinavian context has been the prevalence of play as something with a value in itself (along the lines of, e.g., Huizinga (1938), but even more in the tradition of Norwegian and Danish pedagogical theorists, see Section 1.4) and the creation of informal play spaces - not just for the youngest, but also for older children and youth in after-school (or outside-school/ off-school) settings.

Important work on play culture and its history as well as changes and challenges in today's 'technology driven world' has been conducted in Denmark by scholars like Carsten Jessen (2003).

In her substantial book on 'The making of the Maker Movement', Davies points to the fact that participants in hacker- and makerspaces often refer to making as 'fundamentally playful' and to makerspaces as 'playgrounds' (Davies, 2017: 99). Mark Hatch refers in *The Maker Movement Manifesto* (2013) to play as an important driver in maker processes and environments, and the creative powers embedded in the concept of playfulness when applied to these processes: we may be 'playful with ideas, stretch them to extremes, and morph them ridiculously' (p.26). As argued by Resnick and Rosenbaum (2013):

> …sometimes, tinkerers [makers] start without a goal. Instead of the top-down approach of traditional planning, tinkerers use a bottom-up approach. They begin by messing around with materials (e.g. snapping LEGO bricks together in different patterns), and a goal emerges from their playful explorations (e.g. deciding to build a fantasy castle). Other times, tinkerers have a general goal, but they are not quite sure how to get there. They might start with a tentative plan, but they continually adapt and renegotiate their plans based on their interactions with the materials and people they are working with.
>
> (Resnick and Rosenbaum, 2013: 165).

In sum: makerspaces in after-school settings can focus on being places for creative learning and play. With specific regard to developing communities of learners, Vossoughi and Bevan (2014: 28) point to the specific affordances of makerspaces. They allow makers to:

- Develop collaborative relationships - learning to work together, share tools and ideas, provide assistance to others and embrace intellectual diversity;
- Develop the skills and practices involved in audiencing and sharing projects (such as confidence, communication, drawing connections across artefacts, giving and receiving as tied to the deepening of authentic intellectual activity);
- Develop community;
- Take on new leadership and teaching roles.

## 2.6  MAKERSPACES AS OPEN LABORATORIES

*Klaus Thestrup*

Some recent discussions and developments on open laboratories in Denmark can benefit the future development of makerspaces as emergent places where tools, materials and processes are not defined in advance, or can be changed according to decisions made by and the needs of participants in a makerspace. A group of researchers, consultants, teachers and pedagogues have over the years worked on what is framed as 'Next Practice Labs' (Thestrup, Andersen, Jessen, Knudsen & Sandvik 2015), that in turn is based on the idea of Open Laboratories and Experimenting Communities (Caprani & Thestrup, 2010; Thestrup, 2013).

### 2.6.1 Next Practice Labs

Next Practice Labs are laboratories for next practice and are situated in the very practices they are there to change. The experimenting community has to do with the group of people involved. It has often, over the years and in different research projects, involved children in both schools and kindergartens (Henningsen, 2002[13]; Henningsen, Jerg & Thestrup, 2009[14]; Støvelbæk & MediaPLAYINGcommunities 2009[15]; MediaPLAYINGcommunities 2009[16]; Thestrup, 2013[17]).

These different projects can be mixed groups of all ages, but what they have in common is an experiment in which everybody involved participates and learn during the process, including teachers and pedagogues. The cultural centre of an experimenting community is

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[13] Henningsen, L. (2002). Robotterne går sig en tur/The robots go for a walk. Video documentary. Localized 30.04.2017 https://vimeo.com/62540773

[14] Henningsen, Caprani & Thestrup (2008). I det blå rum. Video documentary in several parts. Localized https://vimeo.com/53535448

[15] Støvelbæk, F. & MediaPLAYINGcommunities (2009). mPc – is what you see: MediaPLAYINGcommunities. Findes også på Vimeo: Klaus Thestrup. Titel:  MediaPLAYINGcommunities

[16] MediaPLAYINGcommunities (2009). mediahandbook: IBAF gGmbH

[17] Thestrup, K. (2013). Det eksperimenterende fællesskab – medieleg i en pædagogisk kontekst. VIA Systime.

the ability to copy and change when wanted and needed. This way of understanding the experimenting culture is centred around play culture (Mouritsen & Qvortrup 2002), creativity and meaning making (Gauntlett & Thomsen 2013), seeing pedagogical processes in kindergartens and after-school clubs as something informal (Jessen 2004) where childre´s culture has an important part to play (Thestrup 2013). The possible change of use of different digital media through mediaplay (Thestrup 2012a[18], 2012b[19]) is a certain area of interest.

### 2.6.2 The Open Laboratory

The open laboratory can be both a way to work and play, activated wherever and whenever needed and in a certain space designed or chosen. In both cases all media, all materials, analogue as well as digital, and all narratives can be brought together in processes that might result in new re-mixings or alterations (Robinson and Thestrup 2016; Thestrup & Robinson 2016). As The Open Laboratory was originally inspired by open theatre where no kinds of theatre traditions are excluded in advance in production processes (Lehmann & Szatkowski 2001), then body, fiction and dramaturgy have an evident place in the encounters between tools. The openness also has to do with communication with the digital world outside the laboratory itself. The Internet represents possibilities for inspiration, collaboration and investigation, reaching out into the world using both synchronous and asynchronous communication.

### 2.6.3 Recent Developments

Recent developments are two projects conducted in 2016 and 2017. One is a project in which pedagogues together with small children developed a practice around the use of a

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[18] Thestrup, K. (2012a). En børnehave møder verden. Pædagogisk Extrakt, 1, 15 pages.

[19] Thestrup, K. (2012b). Kallesok er på facebook. Pædagogisk Extrakt, 1, 2 pages.

digital media base on the use of body and play (Johansen, 2017[20]; Petersen, 2017[21]; Knudsen & Skjerris, 2017[22]). The other is a project where Danish kindergartens and an Italian kindergarten exchanged narratives and cultural expressions (Lauridsen & Howard, 2017[23]). In both cases, the development of new practices took place in the institutions themselves, using and transforming actual spaces and digital encounters to make spaces for experimentation and reflection. This relates to an existing tradition in Denmark of designing actual spaces inside kindergartens to make environments where tools, materials and creative processes play an important part in everyday pedagogical life.

## 2.7 SECTION SUMMARY

*Jackie Marsh*

This section has offered an overview of the different types of makerspaces that might be encountered across a range of settings. Makerspaces, as this section has illustrated, are very much shaped by space, time and context, and they may be placed on a grid as represented in Figure 2, which has two continua, one from informal to formal educational/ learning settings, and the other from temporary to permanent.

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[20] Johansen, S. L. (2017). Sådan kan tablets få små børn til at løbe rundt og juble. Localized 30.04.2017 at http://videnskab.dk/teknologi-innovation/saadan-kan-tablets-faa-smaa-boern-til-at-loebe-rundt-og-juble.

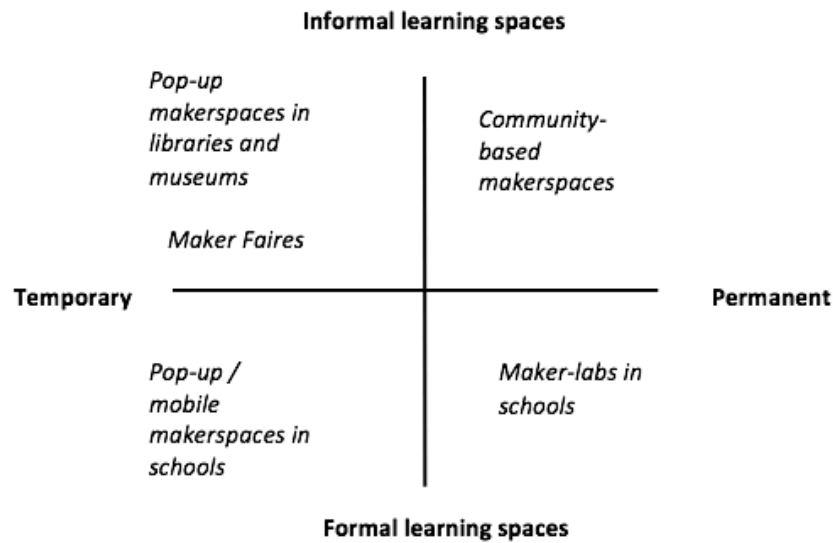[21] Petersen, A. C. (2017). Den store opdagelsesrejse for de helt små. Video documentary. Localized 30.04.2017 at https://youtu.be/1E2tBN6py0w.

[22] Knudsen, J. & Skjerris, M. (exp. 2017). Afrapportering Paddehatten. Report, BUPL, not published.

[23] Lauridsen, P. & Howard, P. (exp. 2017). Cultural Exchange (working title), report, BUPL, not published.

Figure 2: Types of makerspaces

**Informal learning spaces**

*Pop-up makerspaces in libraries and museums*

*Community-based makerspaces*

*Maker Faires*

**Temporary**                          **Permanent**

*Pop-up / mobile makerspaces in schools*

*Maker-labs in schools*

**Formal learning spaces**

Of course it could be argued that, as all models do, Figure 2 presents an overly-simplistic picture. For example, even though makerspaces are set up in schools, with their formal approaches to learning in the curriculum, the learning may then become more informal in approach, and more akin to experiences undertaken in libraries and museums. As well, maker activities undertaken in museums and libraries may be approached in such a didactic manner that they take away agency from the learner, and offer little of what might be characterised as informal learning. Nevertheless, Figure 2 offers a model for the different types of makerspaces that might be set up; models for the learning that occurs in them will look very different in nature.

Reflecting on Figure 2 in relation to young children, it is clear from the literature reviewed in this paper that they are more likely to have access to makerspaces on the left-hand side of this quadrant, if they have access to them at all. This has obvious limitations in terms of being able to choose to undertake maker activities in a spontaneous manner, or being able to work on projects over a long period of time. This needs further consideration by those kindergartens and schools that wish to consider setting up makerspaces.

In the next section of the paper, literature relating to makerspaces and schooling is considered in greater depth, specifically in relation to how such work contributes to learning in relation to specific subjects.

# SECTION THREE
## MAKERSPACES AND SUBJECT LEARNING

This section considers the ways in which makerspaces contribute to learning in various subjects. Whilst it is recognised that much learning in the early years is interdisciplinary in nature, there is value in considering the work to date undertaken in relation to various , distinct, disciplinary areas.

## 3.1 SCIENCE, TECHNOLOGY, ENGINEERING AND MATHS (STEM)

*Hans Christian Arnseth and Anca Velicu*

This review explores makerspaces and young people's orientation towards STEM subjects in makerspaces. It is often taken for granted that making creates interest and learning in STEM. We examine whether any evidence supports this.

### 3.1.1 Makerspaces, STEM and Equity

Barton et al. (2017) study how makerspaces can engage underrepresented youth in STEM topics through community-oriented engineering design. They conducted a two-year critical ethnography study of 36 youths aged 10-14 years. The authors identify three forms of engagement: critical, connected and collective. They argue that makerspaces can support young people from underprivileged communities when making is sustained and connected to their communities. Forms of engagement should be expansive, towards critical, connected and collective ends.

Davis and Mason (2016) studied middle-school-age girls' participation and interest in a makerspace. They conducted a behavioural phenomenological study. Four girls attending

a maker camp were selected for the study. They were between 12 and 14 years old. The researchers were particularly interested in how young people develop their identities in relation to makerspaces or STEM topics. They found changes, particularly in one of the students´ relation to STEM topics. Her previous interests and orientation towards familiar objects occasioned her interest. Specific connections to these aspects by the researcher resulted in more positive valuations of STEM.

## 3.1.2 Learning Arrangements and Learning Outcomes

Bevan et al. (2014) examine how making works as an educative enquiry-based practice in museum settings. They report on a jointly negotiated study by researchers and practitioners. They tested the validity of a set of dimensions of learning with related indicators. The study took place over a period of 18 months. They video-recorded 50 groups working with three different activities in a tinkering studio, namely circuit boards, wind tubes and marble machines. The participants were between 8 and 12 years of age. Through extensive analysis and revision of the model they ended up with four revised dimensions of learning, as outlined in Section 2.4: engagement, initiative and intentionality, social scaffolding and developing understanding.

Tillman et al. (2014) examined the impacts of digital fabrication activities that are integrated into mathematics education. The study was a mixed methods study, and the authors report two key findings: 1) considerable gains in mathematics test scores and attitudes towards STEM, and 2) statistically significant gains on what they term "Probability and Statistics" questions.

Enquiring specifically into learning arrangements in makerspaces and their impact on STEM education, Sheridan and her colleagues (2014) did a multi-site case study. Two analytic strategies were employed: individual case studies using an ethnographic approach (field observations, interviews, text and artefact analysis) and a comparative approach. They found that makerspaces blend together community of practice aspects of learning (e.g. peer-to-peer learning), with elements of participatory culture (e.g. learning by doing, seeing, trying) and more formal settings of art studio or engineering courses

(structured workshops for familiarising participants with tools that are common in every makerspace). This mix was particularly beneficial for STEM education as it allowed the participants to identify the knowledge they needed to complete their self-imposed task.

Bar-El et al. (2016) study whether and how students' voluntary work as mentors in a makerspace impacts on STEM and social empowerment. They interviewed 16 high school students (6 females, 10 males). Three of the mentors did not report any benefit, while nine reported STEM empowerment (learning to use specific digital tools, or understanding the functionality of these tools) and ten social empowerment.

### 3.1.3 Discussion

It is difficult to identify any clear patterns, since there are a limited number of studies in this area. At this point, mainly qualitative methodologies have been employed. Although qualitative methodologies are suitable for understanding a phenomenon and grasping its meaning, it does not allow for more rigorous studies of learning outcomes or the factors leading to changes in attitudes or behaviours. We also notice that some studies focus on a single subject (e.g. maths, Tillman et al., 2014) or a key knowledge domain as being vital for STEM education in makerspaces (e.g. circuitry, Sheridan et al., 2014), while a majority stress an interdisciplinary approach (Bevan et al., 2014; Sheridan et al., 2014).

In terms of children's positioning in makerspaces, we notice three across the literature. Mostly, children are merely participants or learners (e.g. Sheridan et al., 2014). With a deeper engagement in makerspace activities and once the culture of sharing knowledge specific to makerspaces is understood, children can become informal mentors (Sheridan et al., 2014). More rarely, children can also be formal mentors (Bar-El et al., 2016). The notions of equity, social inclusion and democratisation of invention are crucial in many of the papers reviewed. It is a problem that making can easily be seen as a white male middle-class phenomenon, which is an issue that will be considered in Section 4.3.

## 3.2 CREATIVE ARTS AND MAKERSPACES: ART AS ENQUIRY

*Alfredo Jornet and Kate Pahl*

The field of the creative arts as it relates to makerspaces is vast and complex, drawing as it does on a number of epistemological and empirical questions that concern the process and genealogy of creative practice. In order to explore it in a manner useful for foregrounding maker cultures as suitable learning settings, in this review we approach the creative arts as a form of knowing–an epistemology or enquiry–that underlies and therefore is inherent with respect to maker cultures.

Epistemologies of knowing that are embedded in practice generate forms of understanding that differ from classical rationalistic, logo-centric views of knowing (Ingold, 2013). Material thinking is differently weighted and understood through the hands, in felt and embodied ways (Carter 2004). Approaching artistic expression as a form of enquiry thus involves examining the connections between doing (making) and learning, not in terms of relations 'between technology, language, and intelligence but between craftsmanship, song, and imagination' (Ingold, 2000: 292), thereby overcoming the traditional divide between making as something technical/ formal and making as something organic and affective. The creative arts as a form of enquiry have been recognised in the educational literature, where arts-based methodologies recognise the importance of living praxis as a research method (Barone and Eisner, 2012; Barrett and Bolt, 2007) and have informed maker culture epistemologies (Halversson and Sheridan 2014).

We review literature concerning complementary aspects of the creative arts as a form of enquiry. Because of the uniqueness of artistic creation as a form of knowing, the review makes salient those aspects that traditionally are treated as secondary, but which become primary with respect to the way young children learn and know by doing: the primacy of the body, the primacy of emergence and imagination, the primacy of the social and social change. We conclude, briefly, by out that these suggest how maker cultures informed by the creative arts can lead to teaching/ learning in which intellectually knowing and affectively and bodily knowing are no longer divorced.

### 3.2.1 Primacy of the Body

Recognising the arts as a unique and rich form of human knowing relates to a larger trend in the social and human sciences towards acknowledging the situated and embodied nature of human thinking and learning (Roth & Jornet 2013). In this regard, research studies in the arts and in education have begun to explore ties between the creative arts and the embodied and multimodal dimensions of knowing and learning, linking thinking to doing/ practice (Johnson 2010). The idea of children as meaning makers who draw on multiple modes in creative ways has been developed by Kress (1997), Jewitt and Kress (2003) and others, including Safford and Barrs (2005), Flewitt (2008), Stein (2006), Rowsell (2013) and Pahl (2008). Studies of creative (literacy) practices have used a multimodal approach to examine and illustrate the creative and learning potential via which schoolchildren's ideas cross modes and are transformed and remixed in the process (Mavers 2011). Drawing attention to the role of the body in knowing and learning, new approaches to embodiment (Enriquez et al., 2016) and attention to embodiment through theatre and dance have been highlighted (Winters and Code 2017).

### 3.2.2 Primacy of Emergence and Imagination

Artistic practice and approaches privilege process-focused work that is concerned with emergence, open outcomes and knowing by doing (Ingold 2013). As a unique epistemological form, creative art involves recognition of the open-ended, goal-oriented nature of human experience and puts the analytical focus on emergent aspects of learning that can also be found in makerspaces. Creativity research has approached creative teaching and learning in terms of 'possibility thinking' and it has identified ways in which everyday practices can become open and alive to possibility (Jeffery & Craft, 2004; Burnard et al., 2006). Artistic methodologies also draw on the idea of the studio as a makerspace that privileges process over product (Sheridan et al., 2014). Emergent ways of doing and making come alive through experimentation and exploring the marginal spaces of the 'not yet' (Vasudevan & DeJaynes 2013). Place-based production processes see the everyday as a site of possibility, and a utopian approach to method (Levitas 2013). In line with recent arguments in the learning sciences (Jornet, Roth, & Krange 2016), not-

knowing and uncertainty are seen as being as central to the creative learning process as intellectually knowing (Rowsell & Vietgen, 2017; Vasudevan, 2011), which positions makerspaces and other arts-based forms of learning as unique settings for developing children's learning to learn skills.

### 3.3.3 Primacy of the Social and Social Change/Emancipation

Art as a form of knowing can be seen as an expansive approach to problem-solving and being in the world (Coessens et al., 2009; Ravetz & Ravetz, 2016). Epistemologies of the imagination, as identified by Greene (2000), offer different possibilities for thinking and transforming ways of knowing. In the UK, the Creative Partnerships programme opened up a space in which artists could work with schools in different ways (Galton, 2010; Heath & Wolf, 2004; Sefton-Green, 2007). Douglas et al. (2014) have explored drawing both as a form of community building and as a way of finding things out.

Precisely because of their emergent and imaginative nature, the creative arts make possible accomplishing collaborative work across academic disciplinary boundaries. Artistic methodologies are about making space work differently and creating relational structures for different kinds of conversation to happen (Kester 2004). Culture becomes fluid and emergent in these spaces. This has been thoroughly demonstrated in the context of artistic, interdisciplinary design, where performative aspects of creative work have been found to be key in overcoming cultural differences and in collaboration (Jornet & Steier 2015). Ways of knowing through collaborative, interdisciplinary work within particular contexts such as schools and community organisations have been informed by community arts and relational or dialogic arts practice, with a focus on voice (Pahl & Facer 2017). Artistic collaboration can lead to hybrid learning spaces where emergence becomes an opportunity for learning across otherwise exclusive boundaries, thus facilitating a more inclusive education (Kafai et al., 2014; Foster, 2016).
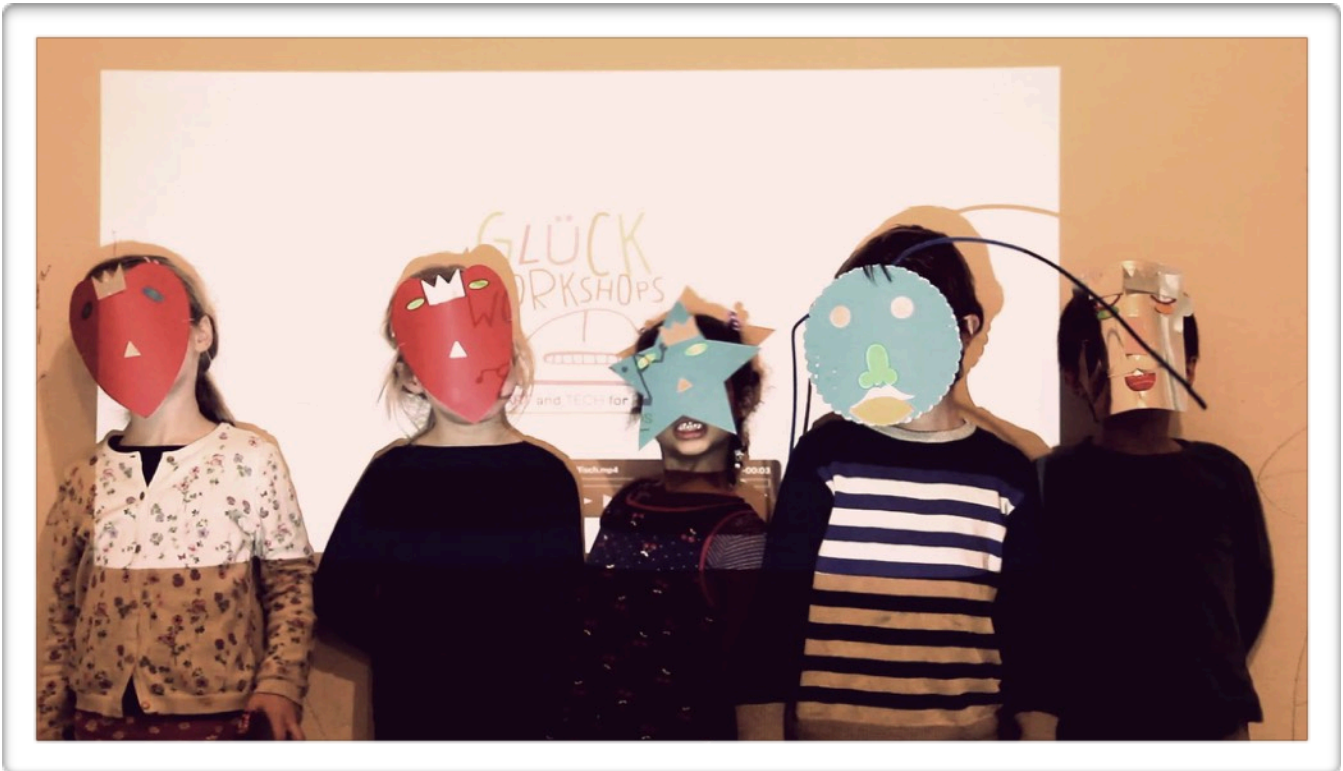
### 3.3.4 Concluding Remarks: Arts and the Unity of Intellect and Affect in Learning

We take from Ahmed (2004) the importance of emotion and affect within learning, and within the arts these things come to the fore. In sociocultural research on learning, the (Russian) notion of perezhivanie, which denotes the unity of intellect and affect and is sometimes translated as artistic, emotional or dramatic experience (Roth & Jornet, 2016), has been found to be useful to capture some of the transformational dynamics that are involved in arts-based learning settings (Fertholt & Nilsson, 2016). The way in which the arts calls on a wider frame of knowing is important for maker epistemologies; as Carter (2004:1) puts it, 'creative knowledge cannot be abstracted from the loom that produced it'. This inseparability is key to the artistic process and will be an important research focus when investigating makerspaces as learning settings in the early years.

## 3.3 DIGITAL SKILLS

*Anca Velicu*

This section will report on research on whether and how digital skills are developed in making processes that occur in a makerspace. The first thing to be mentioned is that there are only a handful of studies focusing specifically on this topic (Blikstein et al., 2017; Taylor et al., 2016; Hughes, 2017), whereas many other studies only mention it inter alia, stressing for instance how makers learn how to use a 3D printer (Bar-El et al., 2016) or an Arduino platform (Sheridan et al., 2014). Thus, due to the widespread access to digital technologies (Martinez and Stager, 2013) in the majority of studies on makerspaces, participants' digital skills are taken for granted and only enhanced after making experience. Another reason for this scarcity of studies on the topic is the fact that many authors report digital skills under STEM related subjects (e.g. Sheridan et al., 2014; Pippler and Hall, 2016).

The most systematically approach for studying the topic is that of Blikstein and his colleagues (2017), who aim to develop an assessment instrument for the new digital skills that are needed and/or developed in makerspaces (called "digital fabrication settings" by the authors) and to test the instrument in different schools. The instrument is meant to measure digital skills, the confidence in having acquired these skills and the relationship between skills and confidence. Relying on a three-step approach to acquiring and measuring digital skills (exposure-confidence-performance), the authors started from the observation that there are three kinds of digital skills to be found in makerspaces – digital creative skills or ICT production skills, computing and programming skills, and exploration and fabrication technology (EFT) skills. After testing the instrument (with 10–18-year-old children from five schools, all of them engaged in makerspaces), Blikstein and his colleagues (2017) found that students have much lower levels of both EFT skills and confidence in their EFT skills compared to their skills and confidence in general computing and ICT production. The authors explain their findings by the much higher exposure of students in their everyday lives to those digital tools that facilitate general computing and ICT production, rejecting the idea that for all technologies there is a relation between exposure, confidence and performance and the idea of children as 'digital natives'.

The two other studies that explicitly approach the topic focus on marginalised communities or 'at-risk' youths, seen as being in need and requiring special help to develop digital literacy. Thus, Taylor et al. (2016) describe how due to volunteers' work in a makerspace specialising in disassemble, repair and refurbish technology, those volunteers and other people from a marginalised community get access to and learn about digital technologies, which increases their chances of getting a job and community participation. Hughes (2017) reports on the results of an interventionist programme aiming to mitigate the digital divide faced by some youths from an alternative care programme. The participants (7 students: 3 males and 4 females, 11-14 years old, in Canada) were enrolled on a five-month programme in which they had to produce a multi-media self-presentation book called 'All about me'. During the process, they learned to use specific apps that facilitated their self-expression endeavours and also acquired some 'soft skills' (i.e. perseverance and collaboration) (Hughes, 2017).

There are other specific digital skills that studies mention in passing as being acquired in a makerspace. For instance, Bar-El and Zuckerman (2016) noticed that a girl in their study spontaneously reflected on the problem of copyright, and thus makerspaces could also introduce children to the ethics of the digital fabrication world (this issue also appears in Martinez and Stager, 2013). Raffalow (2016) mentions that participants in his study acquired skills to operate digital tools in a fabrication process, but also developed communication skills that allowed them to communicate and collaborate online with others and learn about tinkering, and to connect these activities with other spheres of their lives, as friends and family. In another study, Peppler and Hall (2016) found that only 22 per cent of children who participated in a project in a Make-to-learn Youth Contest reported an increase in their STEM-related knowledge (where the authors place digital skills) during the making process. It should be mentioned, however, that three quarters of the products in the contest were made at home, which 'positions families as an important part of youths' learning ecology around making' (p.145). This study is also noteworthy for its innovative approach to collecting data, as the authors favour youths' points of view on their experiences and acquisition in the process of making (Peppler and Hall, 2016).

Although not based on a genuine 'reporting study', it is worth mentioning the parallels between making, writing and coding, not only as technical skills but also as means to

express oneself and communicate (Resnik et al., 2016). These three represent therefore a passage from consuming to producing, from passive use to active engagement with digital technology, from learning for later use to doing it now. All of them also involve an identity shift (to see yourself as a writer or maker or coder), an iterative approach and a share-with-others imperative (or demands for communication and collaboration).

Some authors make a plea for the necessity of better digital skills to be developed in makerspaces, naming purposeful and creative 3D printer usage instead of just knowing how to operate or fix it in a repetitive way (Martinez and Stager, 2013). Blikstein coined the concept of 'keychain syndrome' (2013) as a warning against focusing on the mere output of a digital fabrication process. On this point, other authors argue for the 'effective use' of digital technology in makerspaces (Foth et al., 2016) or for 'critical making' or creating something meaningful for the doer, which links to 'technology and social life, with emphasis on their liberatory and emancipatory potential' (Hughes, 2016: 143). This is relevant for our topic, as the 'effective use' of digital allows for digital participation and is the highest achievement in digital skills, the third level of the digital divide being defined in relation to it (VanDeursen & Helsper, 2015).

As Martinez and Stager (2013) state, with the increasing affordability of 3D printing, the value of just knowing how to use a 3D printer will diminish, and the emphasis will be on the creative process, which allows self-expression. This will also involve the use of design skills, which is the focus of the next section of the review.

## 3.4 DESIGN THINKING AND MAKERSPACES

*Bobby Nisha*

This section will review the requirements of learning conditions necessitated by design and the potential of creative pursuits in maker spaces that can push the learning horizons of young children. Design as a tool of self-expression and transformation is well engrained and hailed as the paradigm where all creative solutions lie, across the domains of arts,

natural sciences and social sciences. As Buchanan (1992) remarks, no single definition can adequately address the diversity of ideas and methods gathered under the label of design. The reasoning pattern in design thinking is abduction, where the 'outcome of the process is conceived in terms of value' (Dorst, 2011:523) and hence requires pedagogic standings in terms of the values we wish to create and the means to help achieve the values we aim for. As Plattner, Meinel and Leifer (2011) argue, this integrates human and technological factors in problem-forming, -framing, -solving and design, with an end-user focus and the need for multidisciplinary understanding and iterative improvement to create innovative products, spatial systems and services. Design is hence about creating and adapting behaviours and values (Plattner et al., 2011). Cognitive interpretations for the learner 'arise out of the "assemblage" (mind/ brain/ body/ building)' and thus important for learning in this context is 'the experience of the corporeality of the learner's time and space when in the midst of learning' (Ellsworth, 2005:4).

Regardless of the domain, in the practice of design thinking the artefacts involved may have a physical form (architecture, planning), a digital form (graphic design, software) or be non-physical (music, dance). A distinctive feature of design learning is its occurrence through a project-based 'studio' whose epistemological groundings are similar in character (not in structure) to makerspaces. The learning setting of a studio is a place where designers express and explore ideas (Boyer & Mitgang, 1996) to arrive at design decisions. Learning is facilitated through the creation of visual representations in 2D and 3D alongside design reasoning to enquire, analyse and test a rationale. Visual and physical analogies are further tested with facilitators that model behaviours, values, design strategies and thought processes (Schon, 1983) to create new variants of geometric configurations. The design studio, in its character and by virtue of its learning settings, encourages communication, critical reflection and collaboration, which is a striking parallel to makerspaces. The makerspace, being a philosophical, 'theoretical and physical embodiment of constructivism' (Roffey and Sverko 2016:3), can pave ways for young children to engage in non-linear epistemologies of learning. The constructivist approach puts the learner at the forefront and stems from the understanding that learning happens through the process of making (Donaldson, 2014). Engaging young children to learn design in makerspaces can shift the axis from ready-made knowledge to the creation of a learning environment that is suitable for innovation and exploration (Donaldson, 2014;

Schön, Ebner, & Kumar; Schrock, 2014); learning by doing is facilitated with hands-on materials for real-world issues (Hatch, 2013). Operating in the constructivist paradigm, creative tasks in maker spaces can incubate the self-awareness of the learner and nurture a sense of self in the learning process. This can lead to children who are determined, independent and creative and more authentically prepared for the real world (Kurti et al., 2014).

Creativity has been highly regarded for its potential to rethink and reform education, and the traditional approaches of 'factory model classrooms' and assessment-driven learning are blamed for having educated our young students away from creativity and in high-stakes testing (Robinson & Aronica, 2015:238). As in the design studio, learner-centred enquiry in the 'making' process can ensure that design thinking scaffolds the process of creation: before, during and after the 'making' phase. Objects will stand as testimony for learners' efforts, evidence of creative thinking, application and problem-solving with existing skill sets. Similar to the model of the design studio, a makerspace can enable learners to persevere through ambiguity and serve as a methodology to solve complex problems through framing, where a frame is an integral part of the way the learner understands a situation; framing in response to complex contexts is key and a crucial element of problem-solving practices in design (Dorst, 2011).

Wagner & Compton (2012) stress the need to prepare young children as innovators, and that can be achieved by incorporating creative thinking into the school curriculum. With makerspaces, design thinking can be embedded into learning practice as a means to develop and nurture the creative capacities of young children. Roffey and Sverko (2016:11) suggest that design thinking must be 'approached with intentionality' and that there is a need to explicitly establish that students are not learning because of being on the receiving end of information, but are learning because they want to engage in solving a problem. They further argue that design thinking has the power to transform students into responsible global citizens committed to creative solutions and able to solve complex global issues, and that this type of 'student innovator' is currently missing in our educational settings (Wagner & Compton, 2012). Hence, makerspaces can enable young learners to identify problems, build spatial and   models, test them for vitality, learn and apply skills, revise ideas, reverse engineer models and share new knowledge with others.

The culture of learning design in a studio such as a makerspace is invested in the learning process, rather than a product (Sheridan et al., 2014), and it offers access to prototyping and conceptual design spaces before arriving at the product; thus, these learning spaces enable the learner to be conscious of the learning process, engage and express themselves, whereby the production process is perceived as a 'realm of possibility' (Levitas, 2013:61). Physical modelling and iterative prototyping can increase the effectiveness and quality of the final product (Roffey and Sverco, 2016). Designers who employ physical models for design iterations outperform those who do not engage in any hands-on pursuit, owing to which creative industries employ prototyping as an integral part of the design process (Dow and Klemmer, 2011) and serve as a means to mitigate design bias or fixation (Viswanathan et al., 2014).

The nature of makerspaces is such that they invite learners to invent new ways to see and new things to say by making new things. Being grounded in a similar constructivist paradigm to a studio-learning environment, 'the learning self is invented in and through its engagement with pedagogy's force' (Ellsworth, 2005:7). This emergence of the self is enabled by its participation in a pedagogy that can take ownership of the resultant conceptual learning. In enabling design learning, the makerspace needs to acknowledge that the learning self is in motion, so the concept of pedagogy needs to mimic its character and be set in motion in interdisciplinary spaces for holistic learning.

## 3.5 MAKER LITERACIES

*Jackie Marsh*

In considering the term 'maker literacies', attention needs to be paid to the problems posed by using 'literacy' as a metaphor, as Barton (2006) points out. 'Literacy' has been tacked on to all kinds of other terms as a marker of skills or competence, such as 'computer literacy', 'information literacy' and so on. Given this proliferation of literacies, of what value is the introduction of a further term? The aim of this brief review of the literature

in this area is to identify the key arguments developed in the field so far, given that it is at an early stage of development, and to consider how the term might be useful in fusing together several strands of literacies studies, including digital literacies and multiliteracies, with the work on fabrication and making.

Some scholars have adopted the term 'maker literacies' to refer to a very broad range of practices. Pawloski and Wall, in a book entitled *Maker Literacy*, suggest that:

> A Literacy Makerspace is an area set aside for children of all ages to tinker, create, and play while building skills from the multiple literacies: reading, science, art, math, art, technology, and so on.
>
> (Pawloski and Wall, 2016: 91).

For literacy scholars, this extension of the term into other subject areas is questionable, as it detracts from considering what is particular about reading, writing and multimodal/ multimedia authoring within a makerspace context. In this sense, it might be of more value to consider maker literacies within a framework of so-called 21$^{st}$ century literacies, in which multimodal text analysis, design and production are at the heart of practice, practice which also fosters other skills, such as critical thinking, problem-solving and communication. A number of models of 21$^{st}$ century literacies exist, each of them reflecting consistent elements of meaning-making, including: communication and creative innovation using a range of semiotic forms; the production and analysis of multimodal and multimedia/ transmedia texts; the ability to engage in critical reflection and problem-solving, and the ability to network (see, for example, Burnett, 2015; Jenkins et al., 2009; NCTE, 2013). In addition, maker literacies builds on previous work within the literacies research field that focuses on the materiality/ (im)materiality of literacy (Burnett, 2015; Mackey, 2016; Pahl and Rowsell, 2010), which outlines the embodied nature of meaning-making, and emphasises the significance of emotion and affect as part of this process.

However, it is the case that there is a need to consider other aspects of what happens in makerspaces in order to develop an expansive model of maker literacies. Wohlwend and Peppler (2015), in an analysis of their maker 'playshops', point to two ways in which literacy is expanded:

First, playshops expand disciplines, such as literacy, to include printless storying, crafting, and other forms of design; this expands the scope of meaning-making practices beyond narrative storytelling in drama and literature disciplines to recognize emerging arts and design. Second, playshops expand paper/print tools to rapidly changing and increasingly intuitive technologies in fields such as digital media production, coding, and electronics in computer science and engineering.

(Wohlwend and Peppler, 2015: 24)

Wohlwend's work has led her to use the term 'maker literacies' to describe 'sets of practices for making and remaking artifacts and texts through playful tinkering with materials and technologies' (Wohlwend et al., in press). This definition is useful, as it places semiotic meaning-making at the centre of maker practice, unlike the use of the term by Pawloski and Wall (2016). Colvert (2015), in her work on children's production of Alternate-Reality Games, also emphasises the importance of social semiotics as a tool for thinking through multimodal making. Colvert maps the processes of multimodal text production and analysis onto Green's (1988) 3D literacy model in order to identify what happens in the stages of text design, production and reception. Green (1988) proposed that there are three elements of literacy - operational (skills-based), cultural (understandings of literacy derived from cultural experiences) and critical (engaging critically with texts in terms of understanding issues of power, voice etc.). Colvert (2015) argues that the processes of text analysis and production (design, production, interpretation and design) can be mapped onto the 3D model in order to understand what is happening in any literacy event. This model was used to inform an understanding of digital literacy recently developed in COST Action DigiLitEY (Sefton-Green et al., 2016), and it can also be usefully applied to a consideration of maker literacies, in which children design, produce, interpret and disseminate a range of texts and artefacts that are created using a very wide range of both digital and non-digital tools and resources (see Table 1).

## Table 1: Maker Literacies
### (adapted from Colvert, 2015)

| | Operational Dimension | Cultural Dimension | Critical Dimension |
|---|---|---|---|
| **Design** | • Use a variety of tools,modes, media and materials to design texts and artefacts<br>• Redesign texts and artefacts | • Understand design principles within a specific social and cultural context, bringing one's own experience to bear on the task | • Reflect critically on design principles<br>• Choose modes, media and materials to use for specific purposes (e.g. to entertain, persuade etc.) and for particular audiences |
| **Production** | • Use a variety of tools, modes, media and materials to produce texts and artefacts<br>• Reuse/ repurpose/ remix texts and artefacts effectively | • Draw on one's own social and cultural experiences in the creation of texts and artefacts<br>• Allow feelings and emotions to shape the production experience | • Reflect critically on the process of production, ask questions such as (i) How do I want to present myself and others in this text or artefact? (ii) What message do I want to convey? |
| **Dissemination** | • Able to use a variety of tools. modes, media and avenues to disseminate texts and artefacts | • Understand the most effective means for disseminating texts and artefacts within a social and cultural context<br>• Reach out effectively to diverse audiences to communicate meanings | • Reflect critically on modes of dissemination to ensure the most effective use of them |
| **Interpretation** | • -Access and understand modes/ media/ materials used in the production of a text/ artefact<br>• Comprehend meaning, interpret through analysis, reflection, synthesis<br>• Relate text/ artefact to one's own prior understanding and experience<br>• Move beyond a literal to a deductive and inferential reading | • Draw on one's own social and cultural experiences in the analysis and interpretation of texts and artefacts<br>• Participate with others in collective review and interpretation<br>• Understand texts and artefacts in relation to the social, historical and cultural contexts in which they were produced | • Reflect critically on the text or artefact that is being engaged with, ask questions such as: (i) Who produced this? (ii) What can be discerned of the producer's intentions? (iii) How has the producer positioned the reader/ viewer/ user? (iv) How do issues of power work in this context? |

Table 1 is not intended to offer an exhaustive model of maker literacies; rather, it outlines some of the skills and understandings that can be employed/ developed when engaged in text and artefact production and dissemination in makerspaces. These may include the technical and fabrication knowledge required to manage and operate tools within a makerspace, such as 3D printers and laser cutters (captured within the 'operational' dimension). Also, Table 1 does not suggest that the products of design and production are all-important. In makerspaces, the process is significant. Hacking, tinkering and making may not lead to the production of a finished text or artefact but, nevertheless, aspects of the process may be analysed using the grid above. Finally, underpinning all of the dimensions and practices identified in Table 1 are the important concepts of play and creativity. Makerspaces can foster play and creativity in early childhood settings, as the work of Wohlwend and Peppler (2015) demonstrates.

Whilst Table 1 outlines the kinds of processes, skills and knowledge involved in meaning-making in makerspaces, it does not pay attention to the subject knowledge that might be developed in these spaces. As children create, for example, models that embody circuits, or use a laser cutter to create a template for a 3D design, they also develop knowledge in the realms of science and engineering, as outlined in Section 3.1. Maker literacy practices facilitate inter-disciplinary learning through these kinds of processes and ensure that STEM subjects are approached in ways that make them enjoyable and meaningful. In such practices, children may engage in traditional reading and writing using alphabetic print, create multimodal, multimedia texts and artefacts and learn key scientific principles. Fluid movements across these different areas, along with an iterative process of creation, mean that pinning down exactly what has been learned in a particular makerspace event is a challenge. Table 1 offers a starting point for tracing what has been learned in relation to Maker Literacies – the assessment of STEM knowledge needs approaches that draw on existing curricula practices in that area.

## 3.6 SECTION SUMMARY

*Jackie Marsh*

Whilst this section has considered various disciplinary areas in relation to making, it is important to recognise that one of the values of makerspaces is that they foster interdisciplinary learning, as outlined in Section 3.5. Indeed, in makerspaces in which children have opportunities to draw on a range of resources to create digital and non-digital artefacts, children will develop knowledge simultaneously in relation to STEM, Arts (together known as STEAM) and literacies, in addition to other relevant subject areas.

An integrated approach to the study of makerspaces is necessary if young children's experiences in these spaces are to be understood in a holistic manner. In the next section of this literature review, a number of cross-cutting themes are reviewed, themes which come into play in all kinds of makerspace provision. These include aspects of identity in relation to the makers themselves, focusing on Peppler, Halverson and Kafai's (2016) third area of study in this field, while other themes addressed in this section include assessment and teacher education.
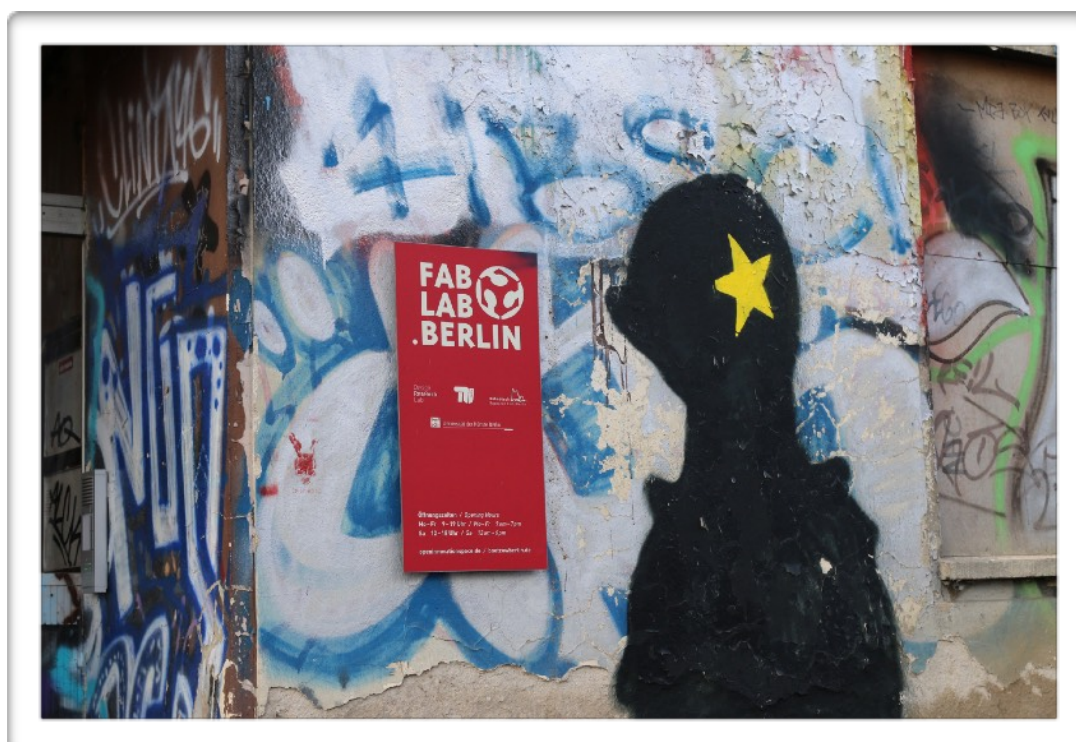
# SECTION FOUR

## CROSS-CUTTING THEMES AND ISSUES

### 4.1  MAKERSPACES IN TEACHER EDUCATION

#### 4.1.1  Making the Case

*Bobby Nisha*

Makerspace experience as a potential tool in teacher education is gaining considerable research mileage. In a review of literature on teacher education that addresses the notion of identity (see Freese, 2006; Hoban, 2007; Korthagen, Kessels, Koster, Lagerwerf, & Wubbels, 2001; Olsen, 2008), Beauchamp and Thomas (2009) suggest that:

> …a teacher education programme seems to be the ideal starting point for instilling not only an awareness of the need to develop an identity, but also a strong sense of the ongoing shifts that will occur in that identity.

> (Beauchamp and Thomas, 2009: 186)

Whilst Identity in general is dynamic and multi-faceted, the constructivist approach in makerspaces education has the potential to engage with the notions of self and identity. Makerspaces as a platform offer the right toolkit to bring learners' identity into the learning space as educators who facilitate learning, rather than relay knowledge to pupils in a didactic manner. Borg (2006:99) suggests that teacher development is 'socially-mediated, non-linear, dialogic and without an endpoint'. It would seem that the use of makerspaces in initial teacher education would enable these principles to be embedded in teachers' training and professional development from the start.

While the use of digital technology and engaging in the act of 'making' may be an enabler of literacies and ideas and a medium of expression for learners, it is important for teacher

education to catch up with the momentum. There is a need for educational approaches to foster creativity and innovation (Blikstein, 2013), and this is of utmost importance in teacher education since, for the educator, it is important to understand this pedagogical approach. Makerspaces by their nature come with an inherent capacity to blur disciplinary boundaries (Blikstein, 2013) and this platform can be highly beneficial for teachers to engage in inter-, multi- and transdisciplinary endeavours. Kurti, Kirti and Fleming (2014) suggest that facilitators of makerspaces in the educational setting should be regarded as 'spacemakers' who, as leaders of this space, must be 'resourceful, failure tolerant, collaborative and always learning themselves, In short, they need to be able to live out the principles and ethics of the makerspaces in front of the students' (Kurti et al., 2014:11). This can be made possible if the educators themselves go through the rigour of engaging with makerspace learning. Hence, there is a need for the pedagogic landscape of teacher education to embed the physical construction of artefacts and making with digital media; this constructive approach can guide an enquiry-based approach to knowledge and contribute to the personal and professional development of the teacher.

### 4.1.2 Making in Practice

*Jackie Marsh*

Whilst the potential of makerspaces for teachers' initial training and continuing professional development is recognised, there are, as yet, few empirical studies that address this issue. The use of makerspaces in teachers' professional development were studied with 25 participants whereby the teacher participants took part in five maker series sessions, a professional development course which included STEAM, engineering design, habitat design, the future of music and bookmaking. Whilst some of the participants found the open-ended nature of the learning difficult, others reacted well to the experience, enjoying the opportunity to be creative (Paganelli et al., 2017). Overall, the teacher participants and presenters regarded makerspaces as educational settings that are 'beneficial' and 'facilitate learning', and the sessions enabled the participants to be creative, work hands-on, collaborate, engage and present their ideas to others. Paganelli et al. (2017:234-5) conclude that makerspaces have 'the potential to support teaching 21st

century skills, such as problem-solving, and could help students gain skills for future careers'.

A study by Cohen (2017) indicates that approximately half of teacher education programmes in the US have some opportunities for the consideration of making, although there is less support for research on maker education. Monty Jones, Smith and Cohen (2017) report on a study in which 82 pre-service and early career teachers were introduced to maker tools and approaches that could be used within elementary and primary classrooms. Whilst the participants felt that the approaches resonated with some aspects of their learning across the other aspects of their training programme, they did express normative, conservative beliefs with regard to how likely they were to use the approaches when teaching, identifying barriers such as lack of knowledge and experience in the area, and potential objections from senior management in schools. Monty Jones, Smith and Cohen (2017) argue that teacher education programmes should address these issues and offer pre-service and early career teachers opportunities to gain knowledge and expertise in this area. In the US, there are also emerging accounts of the use of a makerspace approach for STEM in teacher education (Dousay, Swierczek, Smith and Owsley, 2017; Miller and Cline, 2017).

There are limited examples of practice in other countries. Blackley, Sheffield, Maynard, Koul and Walker (2017) reflect on an Australian project in which 9 female teacher education students worked with 71 Year 5 and 6 girls in a makerspace, in order to engage girls in STEM activities. The research team identified that, whilst the teachers in training expressed a lack of confidence about some aspects, such as being placed in a position where they could not address pupils' queries, they valued the makerspace approach which fostered collaborative learning. It would seem, therefore, that teacher confidence is an issue that is emerging in the studies conducted in this area, and should be a focus for teacher educators who wish to adopt a maker space approach.

There are, as yet, few accounts of makerspaces being used as a means of facilitating pre- and in-service teachers' learning of early years practice. Wohlwend et al. (in press), who outline an approach in which 60 student teachers engaged in a literacy playshop curriculum in the USA; the students used craft materials to hack and redesign action

figures for use in film-making. These practical, hands-on sessions were useful in extending the students' understanding of maker literacies in the early years, enabling them to think through the pedagogical approaches that could be used when they moved into planning their own classroom practice. In relation to in-service professional development, Becker, O'Connell and Wuitschik (2016) report on a Canadian 'primary school's makerspace journey 1.0', a small-scale study in which teachers were able to engage in 'tinkering' spaces offered at lunchtimes on three occasions, and then try ideas out in the classroom. Becker et al. (2016:29) report that, whilst successful, they feel that 'having a designated leader on staff with the pedagogical background in makerspaces who guides this work and continues to move the staff forward is critical to its success'. These two studies suggest that there is significant work to be undertaken in relation to researching the potential of makerspace approaches in pre- and in-service teacher education in the early years.

## 4.2  FAMILIES AND MAKING

*Alicia Blum-Ross*

From cooking family dinners to sewing to DIY and auto-mechanics, informal 'making' experiences are an essential part of the lives of many families – although most parents would not necessarily use this language to describe their shared activities with their children (Roque, 2016). Making, if understood broadly as an iterative and social way for people to come together through shared creation, learning and teaching (Gauntlett, 2011), fits easily within the context of an inter-generational family. Although 'making' is often non-digital, technology also frequently creates a space for shared pleasure and mentorship within family life. Different generations or siblings of different ages frequently engage with and around technology together, from 'co-viewing' or 'co-using' films, TV and video games (Takeuchi and Stevens, 2011; Connell et al., 2015) to using digital media tools like social media or video chat to communicate with far-flung family and friends, as well as those close by (Madianou and Miller, 2012). Digital media play a significant practical role in the family context (Clark, 2013), with parents both relying positively on digital media as a

shared space of engagement but also worrying about the potential negative effects of "screen time" (Blum-Ross and Livingstone, 2016).

In order to encourage or support an interest in digital making, parents must draw on their own interests, values and knowledge – what are sometimes called their 'repertoires of practice' (Gutiérrez and Rogoff, 2003) or 'funds of knowledge' (González et al., 2005) – to inform what and how they teach or learn with and to their children. For parents who lack confidence in their own digital capabilities, this may be challenging, as the narrative that children are 'naturally' better at technology or that they are "digital natives" (Prensky, 2001) can prevent parents from seeing themselves as important in the process of acquiring new creative and digital skills (Roque et al., 2016; Martin et al., 2017). At the same time, if parents are able to overcome these fears there is increasing evidence that there is a wide array of ways in which parents can act not only as technology providers and monitors but also as co-learners/ learning partners and more (Barron et al., 2009).

In the case of very young children, early experiences with making are almost always initiated to some degree by parents or other family members. In the case of visits to museums with hands-on exhibits including makerspaces, parents often seek out experiences that can be shared and mutually enjoyed, but also ones that they define as 'educational' (Ellenbogen, 2003). However, within such spaces, there is a wide variety of parental practices – with some parents simply monitoring and ensuring the safety of their children and other parents more actively participating in and discussing the content (Nadelson, 2013). In considering the impact of these parental practices, there seems to be some evidence that parents who participate more reflexively, helping their children "elaborate" on their experience by asking "wh-" questions (e.g. what/ where/ why/ how), help their children and themselves remember learning outcomes more meaningfully after they leave the learning space (Benjamin et al., 2010).

Makerspaces in museums present a unique setting to reach families with young children in a place they may already be attending, but they also present some challenges to parents' conceptions of how to enact their roles as museum visitors. For families with multiple members of different ages and different aptitudes and concerns, there may be competing agendas in terms of time or interest, so families act as 'dispersed learning systems', not

individual visitors (Brahms and Crowley, 2016). This presents both challenges and opportunities for makerspaces, for example in providing both easy-to-achieve activities that allow for a quick visit as well as more ambitious projects that might require multiple visits to complete (Sheridan et al., 2014). Parents are busy and not always able to devote themselves to the role of 'co-learner' and, as such, making projects that involve parents more meaningfully than brief drop-in sessions or acting as resource providers that are less common (Roque, 2016). At the same time, parents are undoubtedly key resources in establishing an interest in making – and linking this to wider enthusiasm for STEM subjects and knowledge (McClure et al., 2017). Even when they lack subject-area knowledge, parents are knowledgeable about the interests, needs and abilities of their own children (Brahms and Crowley, 2016), and as such they can help them to connect between different sites and forms of learning (Ito et al., 2012). Parents may also play a physical role in children's making, for instance by helping young children to hold tools that they might otherwise lack the dexterity to use in order to help them accomplish their making vision (Sheridan et al., 2014).

## 4.3 MAKERSPACES AND ASSESSMENT

*David Hyatt*

Along with the new affordances provided by makerspaces for learning come new implications for pedagogy and significantly for assessment, in terms of both principle and practice.

At the heart of makerspaces are creativity, exploration and innovation, given that makerspaces are collaborative environments that encourage discovery and problem-based learning (Fleming 2015). As with other constructivist-inspired approaches to learning, makerspace assessment must go beyond the simple evaluation of learners copying a 'delivered' curriculum (Chuter 2016). Standardised summative assessment runs the risk of squeezing the joy out of makerspaces – the essence of motivation/ engagement can be strangled by teachers feeling compelled to train for a test (Kohn 2000).

Standardised assessment struggles to capture the creativity and artistic benefits of makerspaces, including the difficult-to-measure, qualitative pedagogic and leadership skills that children regularly demonstrate during makerspace activities. Standardised assessment does not demonstrate the kinds of measurable outcomes from makerspaces that, in a neo-liberal performative policy context, speak to policymakers. Chuter (2016) argues that much of the makerspace literature still relies on quantitative measurements (Davis et al., 2013) or focuses solely on technical skills (Blikstein et al., 2017) to evaluate the outcomes and effectiveness of makerspace pedagogies. Similarly, a study by Gahagan (2016) on how public libraries assess the outcomes of makerspaces argues that while efforts are being made to assess the outcomes of makerspaces, the reporting of these relies solely on quantitative measurements, such as visitor or participant numbers, and she argues that this approach fails to capture the effects of the service on users.

Chuter (2016) suggests that, in order to focus on creativity and innovation, assessment strategies should focus away from marks as indicators and instead look towards more qualitative methods that demonstrate a maker's thinking and detailed progress' (para. 7). Indeed, the idea of applying a standardised model of testing to makerspace pedagogies may be fundamentally flawed given that, as Barniskis (2014) notes, children may not all be engaged in the same activity at the same time, which implies assessment needs to be individual and bespoke – the assumption of whole-class assessment processes cannot be made.

Assessment has a strong impact on the way students learn (Hattie, 2009). Biggs and Tang (2007) argue that if we wish students to learn particular skills and aptitudes in a makerspace scenario of creativity and innovation, then we should make sure that they know it will be assessed. In other words, assessment must not only be of learning but also for learning. They argue that we should align our teaching, our intended learning outcomes and our assessment design: a process they term 'constructive alignment' (Biggs and Tang, 2007). Chuter (2016) offers three examples of constructively aligned types of assessment in design journals, reflective writing and digital badging (Fontichiaro, 2015), a form of micro-credentialing. Boud (2011) argues that if we wish to develop students' capability for making informed judgements, then we need them to practise using their

judgement, and their efforts in this endeavour should be assessed. Boud argues that assessment should apply not only to the outcome of students' judgements but also to the ways in which they reach their judgements. The processes by which learners arrive at their judgements are largely private to the learners themselves. This makes them better placed than others to assess these processes, through self-assessment.

Flores (2014) similarly argues that peer assessment, either in class or through online open-source sharing, models formative development and collaborative approaches to evaluation of work that makerspace pedagogies also foster. Race (2001) contends that peer feedback is often more meaningful to learners, as the self-evaluation skills derived from peer assessment can have a significant impact on subsequent student engagement and activity. In order to properly assess the work of their peers, students need to have a good understanding of the assessment criteria and the assignment task, both of which promote a deeper approach to learning

One could then conclude that the only authentic, credible forms of assessment for makerspaces are self-assessment, and possibly peer assessment, of the work that learners do and the things they make in makerspaces. One way in which this could be realised is through the use of portfolios, as argued by Seymour Papert (2001), described by Martinez and Stager (2013: 5) as the 'Father of the Maker Movement'. In line with Papert's (1980) constructionist theory of learning, attempts could also be made to adopt an approach whereby criteria and objectives are negotiated between learners and assessors, with the goal of promoting collaboration and creativity (Beghetto, 2005).

## 4.3 GENDER ISSUES

*Rachael Levy*

There has been much written about the value of makerspaces as a strategy that can 'work for everyone' (Klipper, 2014). For example, Halverson and Sheridan (2014: 500) speak convincingly of their belief in the fact that the 'great promise of the maker movement in

education is to democratize access to the discourses of power that accompany becoming a producer of artefacts, especially when those artefacts use twenty-first century technologies'. Given that much of the literature aligns makerspaces with STEM (Kvenild et al., 2017; Saorin et al., 2017), with some specifically claiming that learning through making will support us in reaching 'institutional and policy goals for STEM' (Halverson and Sheridan, 2014, p 501), this has clear implications not only for access to makerspace projects, but also for the ways in which children and young people participate in makerspace activity on the ground of their gender.

It is important to point out at this stage that while the gender gap has narrowed in recent years in relation to occupations, women remain underrepresented in many science, technology, engineering and mathematics (STEM) fields (National Science Foundation, 2017). To illustrate, as Leaper et al. (2012) point out, among the doctoral degrees recently awarded in the US, 'women accounted for 27% in mathematics, 15% in physics, 20% in computer science, and 18% in engineering' (p.268). What is more, there is substantial literature to suggest that STEM subjects are regarded as 'prestigious' and of 'high

status' (Watts, 2014) as well as being 'difficult' and labour intensive (Brea et al., 2012). This is exemplified in a research report by Coe et al. (2008: 1-2) who reported that  in the UK, 'at A-level, the STEM subjects are not just more difficult than non-sciences, they are without exception the hardest of all A-levels'. They go on to conclude that 'to say that one subject is harder than another means that the same grade in it indicates a higher level of general ability'.

This is important because there is a substantial body of literature demonstrating that while girls tend to match boys' performance in maths and science during their teenage years, boys tend to score more highly than girls in 'ability beliefs' (Leaper et al., 2012) with regard to maths and science, as well as beliefs about value (Andre et al., 1999; Kurtz-Costes et al., 2008). This is particularly salient given that there remains a substantial difference between women's and men's pay. The World Economic Forum published the finding that the UK has 'now fallen out of the top 20 most gender-equal countries, with average earnings for women falling from £18,000 to £15,400, while earnings for men remain unchanged at £24,800' (Levy, 2016: 280). What is more, this is clearly a global issue, evident in the fact that the International Labour Organization (ILO) (2015: 2) recently reported that:

> Globally, women earn approximately 77 per cent of what men earn, with the gap widening for higher-earning women. The ILO has noted that without targeted action, at the current rate, pay equity between women and men will not be achieved before 2086.

It is beyond the scope of this review to unpick all of the reasons why this gap exists; however, the fact that skill acquisition in STEM subjects is clearly regarded as carrying more academic prowess than skills in other subjects underlines the importance of ensuring that girls and boys not only have equal access to all curricular subjects but that they feel comfortable with these subjects from their earliest years. I have already discussed this in relation to computer technology (Levy, 2016), where I argued that a number of studies have shown that the culture surrounding computer and other technologies reveals a 'masculinisation of both tools and expertise' (Jenson and Brushwood Rose, 2003: 169), situating technology within a paradigm that is traditionally male (Schofield, 1995; Volman and Ten Dam, 1998; Littleton and Hoyle, 2002).

Given that young children develop ideas and concepts about learning and their abilities to learn during their earliest years in school (Aubrey et al., 2000), this has serious implications for early childhood education. However, it also raises some interesting and important questions about the ways in which makerspaces are currently being accessed, and can be developed in the future, in order to ensure equality on the basis of gender. Holbert (2016: 33) recently raised the concern that the "maker movement" as a whole has tended to have been 'mostly embraced by highly educated and wealthy men'; he goes on to state that as makerspaces are becoming more of a mainstream method used by many to encourage students to engage with STEM, a 'lack of engagement among women and other underrepresented groups is a major concern'. Holbert warns that there is a danger in focusing on 'cultural norms' in an attempt to make such spaces attractive to girls, as this could 'inadvertently perpetuate gender and cultural stereotypes and exacerbate existing community divides' (p.34).

So, what are the implications of this for those working in makerspaces - and especially those working with young children? Further research suggests that the very nature of makerspaces could in fact be very beneficial in supporting gender equality. In their comparison of three different makerspace learning environments, Sheridan et al. (2016) were able to identify common features across the three sites, showing how participants learn and develop through their experiences of making. They concluded that, among other things, the multidisciplinary nature of the environment fuelled engagement and innovation. In this respect, as they point out, 'sewing occurs alongside electronics; computer programming occurs in the same spaces as woodworking, welding, electronic music and bike repair' (Sheridan et al, 2016: 526). This appears to be helpful in breaking down the barriers of 'subject', which have in themselves constrained children for so long within the context of the classroom.

They go on to argue that the breaking down of disciplinary boundaries gives participants the freedom to focus on making, without being pressured or restricted by curricula, assessments or standards. This in itself appears to promote making activity. In fact, Sheridan et al. (2016) give the example of a seven-year-old girl who was observed sewing a blanket for her doll's bed, while watching a boy make a torch on the circuit table beside her. When she had finished the blanket she then sought help to make a lamp to go with

her doll's bed. What is important to note here is that the multidisciplinary nature of the space allowed this girl to move fluidly from a sewing activity to an electronics project. Whilst it is not possible to make any assertion about the extent to which gender influenced the choice of activities for this girl, what we do know is that the makerspace environment appeared to offer an opportunity for this girl to extend her making into a new and unfamiliar domain, one that would not have been possible if she had just been in a sewing workshop.

To conclude, makerspaces have the potential to encourage all children to engage in a variety of activities that they may never have previously considered, due to features such as the multidisciplinary and communal nature of the environment. This gives us a unique and valuable opportunity to promote STEM-based activity with girls and boys within an environment that is free from the boundaries created by the school discourse. This is clearly crucial in order to promote STEM activity as accessible and meaningful for all children, regardless of their gender.

## 4.4 MAKERSPACES AND SOCIAL CLASS

*Fiona Scott*

A review of the literature, 2000–2017, reveals a growing body of academic work beginning to grapple with and theorise the implications of the maker movement for social equity.

### 4.4.1 Makerspaces: Challenging Existing Class Structures and Inequalities?

A number of authors speculate that makerspaces hold the potential to tackle social inequality, putting forward a variety of arguments. Hira, Joslyn & Hynes (2014) speculate that makerspaces might give students freedom to create and build their own artefacts, meaning that students from diverse backgrounds can draw on their unique cultural experiences. Blikstein (2013) makes a broader claim about makerspaces. Arguing that

certain new skills and intellectual activities (e.g computer programming) become periodically essential 'for work, conviviality, and citizenship' (p.204), he argues that the wider adoption of digital fabrication and making capabilities could be seen as part of a process of democratization, bringing "powerful ideas, literacies, and expressive tools to children" (p.205).

Some suggest that making has the potential to bridge the historical divide between academic and vocational education, although for this to happen, we must move past our 'culturally embedded beliefs about mind, work, and social class' (Rose, 2014: 16). Barba (2015) alludes to Platonic philosophy and the historical social division between 'thinkers' and 'doers' to frame the ongoing debate between vocational and liberal education, arguing that the 'shift in emphasis toward design thinking embodied in the Maker movement' (Barba, 2015: 80) may constitute a significant realignment in, or rethinking of, these principles, essentially re-associating higher cognitive skills with manual labour.

Several authors draw on Florida's (2004, 2005) notion of the 'creative class'. Niessen (2010) speculates that the diversification of consumption markets brought about by phenomena such as makerspaces can be seen as stimulating the emergence of a new social class. Tokushima & Tanaka (2015), meanwhile, argue that makerspaces have the potential to create an 'enabling environment for innovations to take place in rural areas of developing countries' (p.2).

### 4.4.2 Makerspaces and the Risk of Sustaining or Exacerbating Social Inequality

At the other end of the spectrum, some warn that makerspaces may simply sustain or even exacerbate existing social inequalities. Toombs, Bardzell & Bardzell (2015) point out that the inclusive rhetoric eschewed by the maker community may serve to obscure the reality that not everyone can be a maker, 'a single mother with three part-time jobs and no car probably cannot be a maker–not, at least, in the sense that "being a maker" is specifically understood in this and other hackerspaces' (p.636). The authors point out that the majority of members of adult makerspaces in their ethnographic study are white,

professional males. There is still little empirical evidence, however, that describes the socioeconomic make up of child participants in makerspaces.

Wyld's (2015) thesis on identity and makerspaces situates maker experiences within a more generic STEM literature (Archer et al., 2010), pointing out that young people's interest in 'being a scientist' as a future career is affected by identity – specifically with regard to social class and the roles individuals consider are available to them. Vossoughi, Hooper & Escudé (2016) make a case for the inherently economic mainstream discourse of making in the US, warning also that certain forms of entrepreneurial making are actually privileged in the media at the expense of other, more everyday, forms: 'The forms of ingenuity present in communities that are not benefitting from dominant economic structures – such as material repair and trade, hacking, making as social or artistic practice, and economic survival – are deemphasized' (p.208).

### 4.4.3 Empirical Work on Makerspaces

Whilst a growing number of academic articles make reference to the theoretical implications of makerspaces for social equity, arguing that makerspaces hold the potential to both improve or exacerbate existing social inequalities, there is currently a noticeable lack of empirical work to substantiate claims in either direction. Undoubtedly, this is an area that requires further study.

Toombs, Bardzell & Bardzell's (2015) ethnography suggests that the membership of adult makerspaces consists predominantly of white, professional males, but there is little empirical evidence to describe the socioeconomic spread of their child counterparts.

Blikstein (2013) makes reference to some empirical work in which there is a particular focus on low-income communities and makerspaces (Blikstein, 2008; Sipitakiat, 2000; Sipitakiat, Blikstein, & Cavallo, 2002, 2004). This range of studies offers some case studies and vignettes illustrating a.) that makerspaces can be (and have been) made workable in low-income communities by utilizing low-cost hardware and repurposed materials and b.) that children in low-income communities experience a disconnect

between the 'making' practices they already enjoy at home and the 'intellectual work' of the classroom.

Gonzalez (2015), meanwhile, employs Bourdieusian theory to critically examine how making specifically in art museums in the US may or may not challenge traditional power structures in relation to social class and museum use. Her thesis contains some case studies that suggest making in museums makes them more 'open', although the author acknowledges that such programmes 'only go so far' (p.146). For example, in the Peabody Essex Museum Maker Lounge, 'a focus on the design process and new technological tools is a strategy to make creativity accessible to public audiences, rather than intimidating them through the presentation of supposed masterpieces' (p.144).

Pabst's (2014) thesis paints a nuanced and interesting portrait of the interplay of social class and community technology centres. Whilst many such centres actively target low-income young people in an explicit attempt to address class inequalities, Pabst concludes that the centres in her study 'were vulnerable to the replication of inequalities' (p.278) as 'youth agency and aspirations were shaped by classed, raced and gendered expectations' (p.279).

### 4.4.4 Makerspaces, Early Years and Social Class

Whilst much of the theoretical literature may be applicable across a range of ages, it is also very noticeable that the bulk of existing literature on makerspaces and social class concerns older children and young adults. There is an absence of literature that specifically considers very young children (3–8), as has been pointed out throughout this paper in relation to various aspects of makerpaces.

### 4.4.5 Summary

A review of relevant literature 2000-2017 reflects the early theoretical thinking that is beginning to emerge with regards to the makerspace phenomenon and its potential

implications for class equity. It is perhaps not surprising that this largely theoretical work provides a fractured narrative: conceptually, it seems, makerspaces hold the potential to improve on or exacerbate existing social inequalities. Whilst a number of case studies and vignettes have been published, it is clear that further empirical work is required before we can start to draw any conclusions about the longer-term implications of makerspaces for social equity in practice. It is also important to note that much of the available literature relates to children and young people as a broad category or refers specifically to the older end of the spectrum. Researching the relationship between makerspaces and social class in early childhood, then, should be seen as a particular priority for future empirical work.

## 4.5 ETHNIC AND LINGUISTIC DIVERSITY IN MAKERSPACES

*Sabine Little*

Since the maker movement is traditionally viewed as 'grounded in gendered, white, middle-class cultural practices' (Vossoughi, Hooper & Escudé, 2016: 208), as outlined in the previous two Sections of this paper, it is important to address the various antonyms of this traditional engagement. Barton, Tan and Greenberg (in press) point out that, as yet, makerspaces that explore communities beyond these cultural traditions are the exception rather than the norm, thus necessitating further work in this area. Vossoughi, Hooper and Escudé (2016) go further, arguing that the maker movement, through the directions it will take in the coming years, may be directly responsible for either exacerbating or helping to overcome existing educational spheres, making a critical approach imperative. Where the previous sections have addressed gender and social class, this section looks at the literature surrounding makerspaces within the context of ethnic and plurilingual environments to explore the affordances of the movement within these spaces.

Blikstein (2013) argues that the manual aspect of making may serve to break down generational barriers, with young makers appreciating the manual labour engaged in by the older generation. Conteh and Kawashima (2008) point out that education systems are frequently in danger of advocating a specific model of parental involvement, influenced by

Western European assumptions of schooling. Makerspaces may offer an impartial, objective space, neither home nor school, for generations to meet and explore together.

In exploring making practices with ethnic minority or indigenous communities, a number of terms and considerations are highlighted. Kafai et al. (2014) refer to the term 'ethnocomputing' in their research, which bridges traditional indigenous sewing techniques with the emergent market of e-textiles. They argue that there is a 'lack of culturally responsive ways to work with underrepresented groups' (p.241) and point out that the crafting of physical artefacts, in combination with the integration of computational components, may assist in bridging traditional and generational gaps, facilitating young learners to become active participants in the most recent technological developments, while still acknowledging their cultural roots. As such, in the process of creation and design, makers enter into a complex, symbiotic relationship known as 'design agency' (Eglash, 2007), where not only the maker influences the design, but the design, in turn, influences the maker.

Nevertheless, the movement is not without criticism. Vossoughi, Hooper and Escudé (2016) question the credentials of the maker movement, stating that, through the way the discourse is currently framed,

> …working-class communities of color are once again positioned as targets of intervention rather than sources of deep knowledge and skill, and dominant communities are reinscribed as being ahead, with something to teach or offer rather than something to learn. (p.212)

In a similar vein, Schwartz and Gutiérrez (2015) argue that '[i]nventing, making, tinkering, designing, are indigenous practices, that is, practices that originate and occur naturally in particular ecologies' (p.577) and demand a more culturally-responsive approach, in which those involved in the maker movement enter culturally indigenous communities as learners, ready and willing to benefit from generations of making experience, rather than imposing a dominant perspective.

Collaborative practices are thus being highlighted, drawing on the strength of local community knowledge, allowing for ownership and control. This then, in turn, has the

potential to solve real-world problems, which, as Shin (2016) argues, ask for real-world solutions and may be tied to issues of social injustice and equity, making it imperative that engineers do not employ neo-colonial methodologies. As such, makerspaces may help in assisting local communities to exercise ownership and power in relation to their cultural identity.

Providing access to makerspaces in certain locations may be problematic, leading to a rise in 'transportable maker locations' (Moorefield-Lang, 2015: 462). Moorefield-Lang (ibid.) links the concept of mobile makerspaces to that of mobile libraries, providing access to communities that cannot sustain a permanent service. While much of the research in this area remains tied to an individual institution (Gierdowski & Reis, 2015; Craddock, 2015), or libraries (Moorefield-Lang, 2015), there is potential for exploring mobile maker spaces with indigenous or ethnic minority communities.

### 4.5.1 Makerspaces and Plurilingualism

The affordances of makerspaces in plurilingual contexts are largely unexplored, making the links to literature explored here tangential, important more for the links they provide for the potential of makerspaces in this area, rather than actual research that has already taken place.

While acquiring literacy in and of itself is a multimodal activity (Kress, 1997, 2000), for children who are constructing knowledge across two or more different writing systems, learning to read and write offers further multisemiotic and multimodal experiences (Kenner and Kress, 2003). In this context, the multimodality of makerspaces may assist in helping children to engage in relevant activities, assisting with the flexibility of mind that is beneficial to multilingual and multimodal communication (ibid.). In line with Blikstein's (2013) argument that the process of making may bridge generational attitudes to manual labour and technology, makerspaces also have the potential to serve as intergenerational, creative spaces where parents may harness the motivational aspects of technology and tools to engage children in communication in the heritage language. This area of research appears to be as yet unexplored.

## 4.6 SECTION SUMMARY

*Jackie Marsh*

This section has addressed a number of wide-ranging topics that emphasise the need to ensure that makerspace education attends to issues of social justice, inclusivity and diversity. Engagement in these issues with all adults who might have an impact on young children's uses of makerspaces, whether they be teachers, student teachers, parents, library and museum educators and/or makerspace staff and volunteers, is important if traditional patterns of access and use of makerspace are to be contested.

In the final section of this paper, the key research questions that need addressing in relation to young children's engagement in makerspaces are outlined, and the contribution that the MakEY project aims to make to the field is specified.

# SECTION 5

## CONCLUSION

### 5.1 FUTURE RESEARCH NEEDS IN THE AREA

*Jackie Marsh*

Throughout this review of the literature, it is clear that few research studies are identified that focus on examining the value of makerspaces in the early childhood years. This is a distinctive gap in knowledge, which needs to be addressed if understanding is to be developed of the way in which makerspaces might facilitate young children's development in digital literacies and creativity. In particular, it seems that the following areas are in need of further research, given the current lack of information:

> (i) The structures and pedagogical approaches that might be adopted in offering makerspaces for young children, including the potential of the use of studio-based approaches that draw in makerspace staff members' expertise.

> (ii) The skills, knowledge and understanding that young children develop in makerspaces, including an examination of the relationships between the kinds of learning that occur, and the affordances of the particular spaces in which they occur.

> (ii) The responses in makerspaces of children who have been marginalised in traditional approaches to STEM, including BME children, children from lower socio-economic groups, girls and children with physical, cognitive and/or linguistic disabilities.

> (iii) Approaches that can be undertaken to assess learning in makerspaces. This could usefully draw on models of good practice in the assessment of early

learning, including the Learning Stories (Carr, 2001) and Mosaic (Clark and Moss, 2001) approaches.

(iv) Inter-generational learning in makerspaces, whether that is children interacting with makerspace staff and volunteers, older teenagers and adults, or their parents and carers.

Throughout this paper, we have identified several other gaps in knowledge, but the ones above are those in most urgent need of addressing, given their significance for policy and practice.

## 5.2 THE PROPOSED CONTRIBUTION OF MAKEY TO KNOWLEDGE

*Jackie Marsh and Kristiina Kumpalainen*

This review has identified that research on makerspaces has been undertaken across a range of disciplines, including computer studies, education, science and technology studies. There is a need to consider the issues from inter-disciplinary perspectives, however, given the nature of learning that occurs in makerspaces. In addition, it is clear that academic and industry partnerships will be of value in this task, given the distinct knowledge and expertise that each sector brings to the issue. One of the key contributions that MakEY will make to the field is to bring together academics from a range of disciplines, working in tandem with makerspace staff, to understand what happens in the making process. Further, the team will undertake empirical projects in six European countries and the USA, which will enable knowledge to be developed of personal, relational and institutional responses to young children's engagement in makerspaces.

First, at the personal level is the child him- or herself. Factors such as identity and interests impact on the choices children make with regard to engagement in digital production and subsequent learning gains. For example, at the personal level, how do young children's vectors of identity, such as gender and ethnicity, impact on their digital

making? Students carry with them the history of their participation in social practices in and outside school. Their histories in person (Holland & Lave, 2001; Wortham, 2004) – that is, their unique trajectories of past participation in and across social contexts, sedimented in their identities – are powerful mediators of their present activity. However, students' identities are not determined by their past and present conditions; people and the social practices in which they participate co-develop over developmental time. Moreover, through their imagination, students can project themselves onto alternative futures by enacting projective identities (Francis, 2008; Gee, 2003). Taking part in makerspaces might bring forth a space of authoring new actual and projected identities, which could be important in orientating children towards future participation in activities involving making, as in STEM/ STEAM. At a personal level, therefore, the project will identify the beliefs and practices of makerspace employees and volunteers, library and museum educators, early years practitioners, across Europe with regard to the value and development of makerspaces for the 3–8 age group through the use of an online survey. In terms of the children themselves, the project will identify the meanings and motivations children attach to their engagement in making activities in each of the case study settings, and explain how these motivations interact with the demands of the makerspace. The project will also demonstrate how children's experiences and identities in the makerspace reshape their interest in and identification with digital literacy learning and creativity, and will offer insights into the kinds of digital literacy skills and creative competences children develop through their participation in makerspaces.

Second, at the relational level, we are interested in exploring the nature of social interactions and learning practices, including collective creativity, that arise in maker spaces. Heterogeneity, complexity and conflict are central features of any social practice (Rajala & Sannino, 2015; Kumpulainen & Renshaw, 2007; Lave, 2008) and thus it will be important to trace the continuous negotiation and conflict between the varied agendas, identities and interests of the children, cultural industry professionals, teachers and other stakeholders taking part in the activities. We are also interested to understand the ways in which the social and material resources of makerspaces support diverse children's joint engagement, digital learning and creativity. At a relational level, therefore, MakEY will shed light onto what characterises the social interactions and learning practices that arise in the digital makerspace, and will illuminate how diverse children engage in the social

interactions of the makerspace. It will also demonstrate how the social and material resources of the makerspace support diverse children's engagement, digital literacy and creative design skills.

Third, at the institutional level, we want to investigate what differences operate when considering makerspaces that are situated in different contexts, such as Fab Labs, museums and kindergarten classrooms. The project aims to unpack the dynamics between the motivations that children bring to their maker activities and the demands that these activities pose on their engagement, learning and creativity. In doing so, the project will disclose the developmental potential of makerspaces for individual growth, as well as for institutional transformation. A focus on the agentive powers of individuals and on their personal ways of interpreting and experiencing the demands of activity is an often neglected and emergent area of cultural-historical theorising (Engeström, 2011; Stetsenko, 2013). At an institutional level, therefore, the project will identify the perceived institutional/ organisational barriers to the use of makerspaces for children aged 3-8 in community makerspaces, early years settings and schools, libraries and museums. It will illuminate how makerspaces are integrated into these institutions, including considerations of social organisation, space and time arrangements. The project will demonstrate to what extent the makerspaces studied and their practices create equitable opportunities for children's learning and identity development and how this process operates at an institutional level. The project will identify what kinds of practices - pedagogical, assessment, material provision - best support young children's engagement in makerspaces and suggest how this knowledge might be used to inform future provision for makerspaces in both formal and non-formal learning spaces. The project will also demonstrate the value of the partnership between academic and non-academic participants in creating makerspaces for young children.

Finally, at a societal level, the project will indicate the potential of makerspaces to develop the kinds of skills and knowledge required to enable Europe to compete globally in future employment markets. Notwithstanding the fact that such skills may have been over-stated with regard to future work opportunities (Willett, 2016), it is clear that digital technologies will inform various employment paths in future years. The various contexts for each
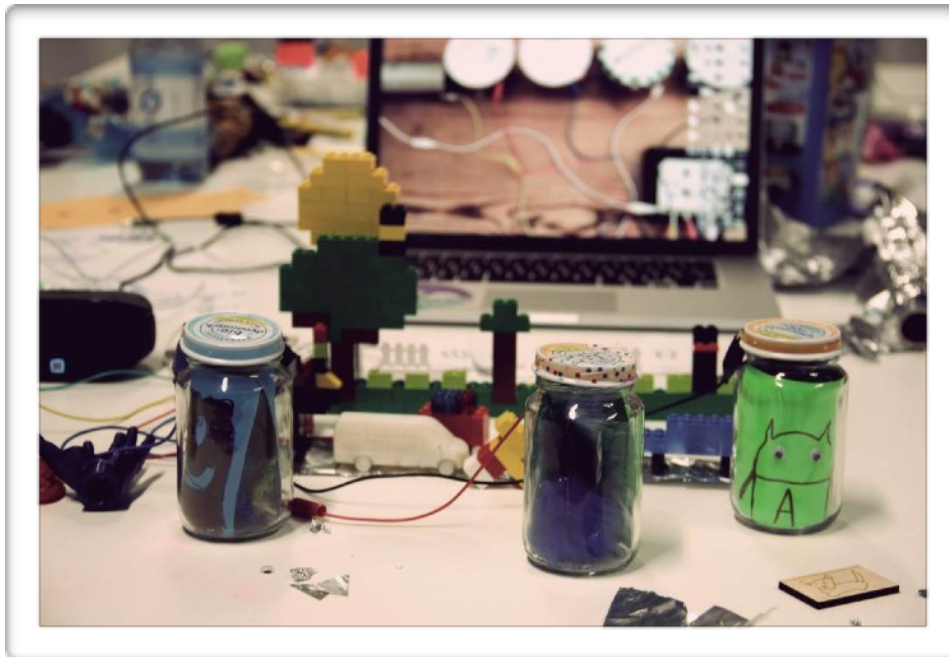
makerspace in the MakEY project will afford insights into specific areas, such as the potential for collaboration with museums, the value to be gained from collaborative research with early years practitioners and the value of makerspaces for enhancing intercultural exchange and understanding between multilingual children from diverse social, ethnic and cultural groups. Each case study will take place in a different context and in slightly different forms, enabling perspectives to be developed on the value of various models of academic and non-academic partnerships and the nature of country-specific impacts on this work. Collectively, analysis of the case study data will lead to the development of educational tools and resources to inform the future development of makerspaces in non-formal and formal learning spaces, taking account of the needs of the various partners. On completion of the project, we aim to make recommendations for policy and practice that will foster innovation and entrepreneurship in SME makerspaces and facilitate the use of makerspaces for enhancing digital literacy in early childhood educational institutions and non-formal learning spaces such as libraries and museums.

## 5.3 FINAL WORDS

*Jackie Marsh*

In this paper, we have surveyed the literature in an attempt to identify the current state of knowledge about the use and value of makerspaces in early years settings. As we have identified, there is limited literature in this field, but there is a range of valuable knowledge that has been developed in relation to the use of makerspaces with older children and young people that can be drawn on to inform work with younger children. In this sense, the MakEY project will be building on strong foundations, and contributing to the collective task of furthering our understanding of the value of makerspace pedagogies for fostering digital literacy and creativity.

The MakEY project aims to make a contribution theoretically, empirically and practically to this field. In relation to theory, we aim to develop new and innovative conceptualisations of young children's digital literacy and creative skills and knowledge through dialogue between social and cultural activity theory and new materialism/ post-humanist philosophy. Empirically, the project will contribute to knowledge about the potential makerspaces have for the development of young children's digital skills and knowledge and creativity, including creative design, as outlined in the previous section. The project will lead to important policy and practice insights for addressing the development of children's digital literacy skills and understanding in both formal and non-formal learning spaces.

The MakEY project builds on established relationships between specific partners within the network, as well as new partnerships, and the aim is to establish a long-term global network that will inform future research, policy and practice in this area. Our international partners, all active in researching makerspaces within their respective countries (Australia, Canada, Colombia, South Africa, the USA) and eminent scholars in the field, will join with us in developing a road map of a relatively unknown and unmarked territory - the landscape of makerspaces in the early years. This paper offers an initial rough sketch of that landscape and is the starting point for our journey.

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