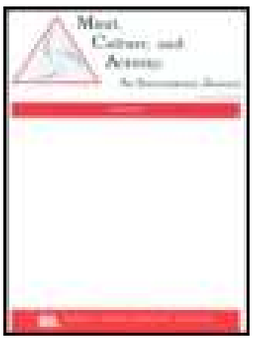

Routledge
Taylor & Francis Group

Mind, Culture, and Activity

ISSN: 1074-9039 (Print) 1532-7884 (Online) Journal homepage: https://www.tandfonline.com/loi/hmca20

Makerspaces in early childhood education: principles of pedagogy and practice

Jackie Marsh, Elizabeth Wood, Liz Chesworth, Bobby Nisha, Beth Nutbrown & Bryony Olney

To cite this article: Jackie Marsh, Elizabeth Wood, Liz Chesworth, Bobby Nisha, Beth Nutbrown & Bryony Olney (2019): Makerspaces in early childhood education: principles of pedagogy and practice, Mind, Culture, and Activity, DOI: 10.1080/10749039.2019.1655651

To link to this article: https://doi.org/10.1080/10749039.2019.1655651

Published online: 30 Aug 2019.

MIND, CULTURE, AND ACTIVITY
https://doi.org/10.1080/10749039.2019.1655651

Routledge
Taylor & Francis Group

ORIGINAL ARTICLE

OPEN ACCESS Check for updates

Makerspaces in early childhood education: principles of pedagogy and practice

Jackie Marsh, Elizabeth Wood, Liz Chesworth, Bobby Nisha, Beth Nutbrown, and Bryony Olney

University of Sheffield

ABSTRACT

The aim of the study reported in this paper was to identify the value that makerspaces can have in early childhood education (ECE). Drawing on data from research on makerspaces in four early childhood settings in a northern city in England, part of an international project on makerspaces in the early years ("Makerspaces in the Early Years: Enhancing Digital Literacy and Creativity" or MakEY), we identify three key principles that are integral to this provision: maker agency, maker funds of knowledge, and postdigital maker play. The paper identifies that makerspaces lead to the development of skills and knowledge that will become increasingly important in societies that are becoming highly technologized.

As the digital age is impacting on the lives of young children, they have increasing access to a range of digital technologies in homes and communities from birth (Chaudron et al., 2015; Marsh et al., 2018). However, many governments to date have paid scant attention to the need to develop children's digital literacy skills (Sefton-Green, Marsh, Erstad, & Flewitt, 2016). In early childhood education (ECE), there is evidence that children's digital play practices are in advance of teachers' adaptation of curriculum and pedagogical approaches that incorporate digital technologies, digital media, and popular culture (Fleer, 2017; Wood, Nuttall, Edwards, & Grieshaber, in press). These problems indicate an urgent need for populations to develop the skills and knowledge required to navigate a complex technological world, and contribute to social, economic and cultural developments. Furthermore, the rapid development of new technologies highlights both the potential and the need for transformative pedagogies (Wood et al., in press; Yelland & Arvantis, 2018), through which young children can acquire the related skills and practices to participate in contemporary society.

A recent development in terms of the skills and knowledge relevant for the so-called "fourth industrial revolution" (Schwab, 2016) is the advent of makerspaces, which, as Sheridan et al. suggest, are "comprised of participants of different ages and levels of experience who work with varied media, but a commonality is that these spaces all involve making – developing an idea and constructing it into some physical or digital form" (2014, p. 507). The increasing use of these spaces – termed variously as makerspaces, fabrication labs (Fab Labs), hack spaces, and so on – has been linked to the North American Maker Movement, a grassroots phenomenon that fosters a DIY approach to making and has led to the provision of Maker Faires at which makers share their products, passions, and expertize. In relation to education, a number of studies have identified the potential that makerspaces have for learning, given that they can foster curriculum content knowledge in science, technology, engineering, and mathematics, alongside other areas of learning (Halverson & Sheridan, 2014; Litts, 2015; Martin, 2015; Sheridan et al., 2014). However, Peppler, Halverson, and Kafai (2016) suggest that the majority of the research on makerspaces is related to adolescents and adults, and

CONTACT Jackie Marsh j.a.marsh@sheffield.ac.uk University of Sheffield, 241 Glossop Road, Sheffield S10 2GW

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/hmca.

there is a need to explore the potential that makerspaces have for ECE, specifically for pedagogical practices. Early accounts of such work (Blum-Ross, Kumpulainen, & Marsh, in press; Brahms & Crowley, 2016; Brahms & Werner, 2013; Marsh et al., 2017; Wohlwend & Peppler, 2015; Wohlwend, Peppler, & Keune, 2016) suggest that makerspaces offer much potential for ECE.

The project reported upon in this paper, "Makerspaces in the Early Years: Enhancing Digital Literacy and Creativity" (MakEY) was a collaboration among seven European countries and involved three museums in the Bay Area, United States. The project focused on researching the role and potential of makerspaces in the learning of young children (those aged under 8) in both formal and nonformal settings. The project built on the North American experience but also recognized that 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 part of everyday practice, at least until recent years, when pressures related to a performance-oriented approach have led to a greater emphasis on the "basics" in some areas (Ringsmose & Kragh-Müller, 2017). One aim of MakEY, therefore, was to consider how far makerspaces in ECE can build on these well-established traditions to encompass contemporary digital, social, and cultural practices. A further aim was to consider the value of makerspaces in relation to three areas of influence – the personal, relational, and institutional – and research questions were identified in order to explore each of these levels (see http://makeyproject.eu) while recognizing that the three levels are interrelated.

In this paper, we suggest that makerspaces in early childhood settings enable children to develop individual agency, they foster social interaction and enhance relational knowledge through enabling children to draw on their maker funds of knowledge, and, finally, they can shape institutional pedagogical practices in ways that enable children to move seamlessly across digital and nondigital domains in their maker play, a phenomenon captured by the concept of *postdigital play*, (Jayemanne, Apperley, & Nansen, 2016). These three concepts are outlined in the following section.

Theoretical framework

The work of Piaget (1936/1953) and Vygotsky (1978) has informed ECE practice internationally and remains influential in contemporary policy frameworks (Pramling-Samuelsson & Fleer, 2009). However, the constructivist and developmental orientations of Piaget's theories have been extended through contemporary interpretations of sociocultural theories. Daniels (2016, p. 4) draws attention to how Vygotsky's legacy has been developed over time and applied in the emerging dialectics of post-Vygotskian and related social theories. In early childhood, play is the leading activity, which foregrounds children's needs, motives, and interests, as well as their participation in diverse social and cultural practices. However, because the social situation is dynamic, children's learning and development continuously evolve in relation to existing and new practices. In the context of such rapid technological innovations, not only do children's everyday activities change in relation to new tools and materials, so too do children's opportunities and motivations to use those tools and materials in their own ways.

Consistent with the work of Rogoff (2003), we propose that children's freely chosen activities in makerspaces can be understood by combining three perspectives: personal–individual, social–relational and cultural–institutional. At the personal level, the concept of agency is central to an understanding of how children become more independent in a learning context. Agency involves children making personal and interest-driven choices that are empowering because they can follow deep inquiries that draw on their funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992) and life experiences. In this paper, we suggest that makerspaces offer rich potential for the development of agency at an individual level, enabling children to have choices over what they make, when, and how, which we term *maker agency*.

These perspectives, in turn, support a relational position, which indicates the ways in which makerspaces enable participants to be active and self-directed learners who are able to demonstrate

tool-mediated and relational agency (Edwards, 2005; Halverson & Sheridan, 2014; Martinez & Stager, 2013; Sheridan et al., 2014). As they move across dynamic social and cultural contexts, children encounter everyday/informal knowledge and scientific/curriculum knowledge that enables them collectively to build concepts, skills, and new understandings with peers, adults, tools, and materials. Thus, although the traditional child-centered processes of exploration, discovery, and playfulness remain central to sociocultural theories, the emphasis is more on contexts and communities rather than the individual child. The concept of child-centeredness has been contested for its universal assumptions about development (Cannella, 1997) and has led to suggestions that individualized approaches to pedagogy serve to reproduce gendered and racialized bias (Langford, 2010). Furthermore, child-centeredness can be levered to proscribe what is developmentally appropriate in ways that restrict children's access to knowledge and ways of coming to know, as a means of protecting them from difficult issues and everyday events. The makerspace movement aligns with child-centeredness in its commitment to enabling users to pursue their own passions (Hsu, Baldwin, & Ching, 2017), but its roots lie not in an individualized agenda of self-improvement but in a participatory, democratic, and commons-oriented vision (Vasilis, Vasilis, & Wolfgang, 2017). In relation to Rogoff's (2003) second plane of analysis (relational), in this paper we argue that the maker movement has the potential to contribute to contemporary theories that place children's prior experiences and funds of knowledge (Moll et al., 1992) at the heart of relational pedagogical practice. Drawing upon Hedges, Cullen, and Jordan (2011) and Chesworth (2016), we argue that the concept of funds of knowledge can facilitate a reconfiguration of child-centeredness, which shifts the focus from individual children toward their participation in sociocultural practices. From this perspective, child-centered pedagogical approaches must begin by recognizing the knowledge and practices that children bring with them to ECE settings, and their agency and motivation to become more skillful and more knowledgeable. Research indicates that children's funds of knowledge relate to their interests, which can be expressed through children's choices and participation in a range of activities (Chesworth, 2016, 2018). However, as Hedges and Cooper (2016) have argued, interests should not be seen just as activity choices but as fundamental inquiries that have meaning and content for individuals, that foster meaningful relationships with others and are shared within the community. Children's interests and funds of knowledge incorporate cognitive, affective, imaginative, and relational qualities, and these are expressed in their play choices and activities (Chesworth, 2018). Through tinkering, hacking, and playing in makerspaces, they develop maker knowledge. In these activities, children can bring to the site of learning their previous experiences of making in the home, which frequently include digital media (Marsh et al., 2015). In this paper, we draw attention to the role that these maker funds of knowledge have in makerspaces, given the extent to which children bring their experiences and knowledge of digital making from home, and the potential this has for their learning in ECE settings.

In terms of considering the institutional level in relation to children's experiences of makerspaces in early childhood settings, the role of play is paramount. Play is central to early childhood principles and practice, specifically the links between play, creativity, and learning, and policy documents ensure that it informs institutional-level approaches to practice (Wood & Hedges, 2016). From a Vygotskian learning leading development orientation, play involves cognitive processes linked to creativity, such as problem-solving, metacognition and creative practice (Wood, 2013) as children transform everyday tools, symbols, and meanings through individual and collective activity. Children's creativity in play is expressed through their semiotic, symbolic, and multimodal communicative practices, as well as artifacts and tools, that contribute to collective meaning-making. Children draw on a range of modalities that incorporate movement, embodiment, gestures, gaze,

facial expressions, drawings, pictures, diagrams, models, and other cultural tools and artifacts. These modalities enable children to communicate and illustrate their meanings, perspectives, and ways of understanding their social, material, and cultural worlds in ways that produce their own development. They also convey their interests, funds of knowledge, and identities through different modes of participation (Chesworth, 2018).

Play has also been identified as an important factor in the provision of makerspaces that foster engagement, creativity, and social participation. 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 play, construction play, physical play, creative play, artistic play, make-believe play, technological play, and 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 study conducted by Whyte (2016) of makerspaces in an Ontario library, the researcher found that play was the first theme that emerged from a review of her data. The adults attending the makerspaces engaged in playful behaviors, and they used terms such as "'play' or 'play around with' to describe their interactions with the tools" (Whyte, 2016, p. 4). However, the nature of play has changed over the years, with technology playing an increasingly significant role (Marsh & Bishop, 2014). While various concepts have been developed to explain the nature of contemporary play in a digital landscape, such as connected play (Marsh, 2017), and ecology of play (Arnott, 2016), in this paper we draw on the concept of postdigital play (Jayemanne et al., 2016). As outlined in the work of Marsh and Arnott, among others, The term emphasizes the way in which the digital is so embedded in everyday play practices that it is no longer meaningful to consider the digital in contrast to nondigital. However, the use of the term is aligned with a broad range of sociological and philosophical thought on the nature of culture and society in a rapidly changing era (e.g., Berry & Deiter, 2015; Jandrić et al., 2018). Cramer (2015) argues, however, that the term postdigital should not be used to present a case for a historical juncture between the digital and nondigital, as the relationship between these two will always be subject to dynamic change. Rather, it signals that because of the level of interrelationship between the digital and nondigital in everyday life, paying attention to the way they are separate is somewhat outmoded. In this paper, play is considered in relation to children's experiences in makerspaces, extending the unit of analysis to postdigital maker play.

The paper, therefore, addresses these three concepts – maker agency, maker funds of knowledge, and postdigital maker play – in relation to Rogoff's three planes of analysis: personal, relational, and institutional. In the next section of the paper, we outline the research design.

Methodology

The paper reports on the four case studies that were conducted in a city in the north of England as part of the MakEY project. The case studies were undertaken with two nursery schools and two primary schools. The first setting was a nursery school that cares for 90 children aged 3–4. The nursery school serves diverse racial and ethnic communities and many children there speak English as an additional language. The second setting was a nursery unit with 45 children aged 3–4, which is part of a primary school in a primarily White, working class area of the city which is one of the most socially deprived nationally. The third setting was a Year 2 class in an inner-city Church of England (religious) primary school, with 28 children aged 6–7, the majority of whom were White. There was some diversity in the class with regard to socioeconomic status, but many of the children came from middle-class families. The final setting consisted of two parallel Year 3 classes in a primary school, with 60 children, aged 7–8, in total. The school was ethnically diverse and located in an area of the city that has indicators of social deprivation. The schools were invited to participate in the project because they had had previous involvement with the University. The makerspace projects were planned in advance in collaboration with the teachers. In the first three settings, practitioners took

part in preproject training events, in which they were introduced to some of the maker activities that the children would undertake. The projects involved two artists and a maker, in order to draw on their expertize and provide role models for children. They were engaged in the planning and delivery of the pop-up makerspaces. Table 1 provides an overview of the projects.

In all of the settings, while the emphasis was on activities that led to the production of a range of artifacts, there were also opportunities to play and experiment with materials. Tinkering and hacking are important elements of makerspaces (Peppler et al., 2016). The nursery schools, for example, set up maker tables in the outdoor areas in which children were able to engage in open-ended play with the materials. At the end of the projects, an exhibition of the children's work was held in the city center, which participants from all of the settings, with the exception of Setting 1, visited.

Data were collected in a number of ways. Researchers made field notes of sessions observed. A static video camera was set up on a tripod to capture making at tables. A research assistant also used a handheld camera and tablet to take photographs and films. Children were offered the opportunity to wear GoPro chest cams during the workshops in order to capture their activities. Finally, six staff were interviewed about the project (the head of Setting 1 and two of the nursery school teachers, the head of Setting 2, the teacher of Setting 3, and one of the teachers of Setting 4) in addition to two artists (who each worked with a setting) and a maker (who worked with two of the settings). Interviews took between 30 minutes and one hour. The teacher in Setting 4 could not be interviewed in person and so submitted her answers to the interview questions via email. Table 2 offers a summary of the data collected.

In the overall project, 12 research questions underpinned the data collection, clustered in relation to the three planes of analysis identified by Rogoff (personal, relational, and institutional). In this paper, three of the 12 research questions are focused upon, as follows:

Table 1. Overview of the MakEY projects.

Setting 1: Nursery School	Setting 2: Nursery School
Topic: Light and color ***Aims***: To introduce children to the concept of a circuit through a variety of activities which involved making circuits ***Activities:*** (i) Making light boxes with cardboard boxes that had clear tops, using cellophane and DIY torches (flashlights); (ii) Creating light shows in a blackout tent, using the app PABLO; (iii) Printing the light shows off as stickers, using the HP Sprocket printer; (iv) Using Play-Doh with circuits to create models; (v) Creating animated films using an overhead projector and colored transparent shapes, a tablet, and the app iMotion; (vi) Drawing with circuits; (vii) Drawing on an interactive whiteboard and projecting light shows onto the screen; (viii) Creating calendars for parents using images of the light shows.	***Topic***: Lighting ***Aims:*** To introduce children to the concept of a circuit through a variety of activities which involved making circuits to light up houses, streets, and Christmas trees ***Activities:*** (i) Creating a model of their homes with their parents (completed at home); Creating a light for inside their house, using copper tape and LEDs on a laser-cut base; (iii) Creating street lights using copper tape and LEDs on a laser-cut base; (iv) Creating a Christmas-tree shape using card triangles, which were then laser cut; (v) Placing lights on the trees, using copper tape and flashing LEDs; (vi) Creating green-screen animated films of the children singing Christmas songs in front of an image of a forest of their circuit trees; (vii) Creating green-screen animations with their houses and dolls.
Setting 3: Primary School	**Setting 4: Primary School**
Topic: The Moomins (based on the books by Tove Jansson) ***Aims***: To develop imagination and creativity as children respond to the story through maker activities ***Activities***: (i) Watching a theater performance with Moomin puppets; (ii) Drawing Moomin characters, which were then laser cut; (iii) Using the wooden characters in shoebox theaters; (iv) Writing play scripts for their theaters; (v) Creating clay Moomin models; (vi) Scanning those using Qlone app and creating 3-D digital models; (viii) Printing the 3-D digital Moomin figures on a 3-D printer; (ix) Using the clay and 3-D printed models to make green-screen animated films using the app iMotion; (x) Importing the 3-D digital Moomin models into Google Tilt Brush and creating a virtual reality Moominvalley.	***Topic***: Imaginary playspaces ***Aims***: To create imaginary playscapes using virtual reality ***Activities***: (i) Identifying favorite playspaces in the neighborhood, using tablets; (ii) Printing off the images and using them as a basis for collages of imagined spaces; (iii) Creating 3-D clay models of elements in their imagined playspaces; (vi) Scanning those using Qlone app and creating 3-D digital models; (v) Importing the 3-D digital models into Google Tilt Brush and creating a virtual reality imaginary playspace.

Table 2. Summary of data collected.

	Number of GoPro films	Number of handheld and static camera films	Hours/ mins/secs of video data	Number of photographs	Files of children's work (.stl/. obj./mov)	Number of days of fieldnotes	Number of interviews with practitioners	Number of interviews with artists/ makers
Setting 1	51	97	17.56.51	73	25	5	3	1
Setting 2	55	75	18.38.57	101	17	5	1	1
Setting 3	31	26	9.05.56	336	245	4	1	1
Setting 4	93	80	28.38.31	149	319	2	1	1
Total	**230**	**278**	**74.20.15**	**659**	**606**	**16**	**6**	**4**

Personal level

- What are the meanings and motivations children attach to their engagement in making activities in each of the case study settings, and how do these motivations interact with the demands of the makerspace?

Relational level

- What characterizes the social interactions and learning practices that arise in the digital makerspace?

Institutional level

- What kinds of practices – pedagogical, assessment, material provision – best support young children's engagement in the makerspaces, and how might this knowledge be used to inform future provision for makerspaces in both formal and nonformal learning spaces?

In relation to the third research question, the focus was on pedagogical practices related to play. Eighteen codes were agreed upon by the international team in relation to these three questions, and these were applied deductively to the data, in addition to inductive coding taking place. Codes were then clustered into themes at the second level of analysis (Braun & Clarke, 2006). Three key themes that emerged from this process are discussed in this paper, which relate to the three planes identified in the research questions: maker agency (personal level), maker funds of knowledge (relational level), and postdigital maker play (institutional level).

Ethical considerations were paramount at all stages of the study. Parental consent was gained for the separate elements of the project so that parents could opt out of consent for filming, for example, while being able to consent to overall participation. The notion of assent was deployed in relation to the children so that if children joined the makerspace but then seemed tired or disinterested, they were reminded that they could choose other activities. Children volunteered to wear GoPro chest cams, but they could choose to take them off when they wished to do so, and if they appeared to be uncomfortable with the camera, researchers would initiate a discussion about whether or not the child wished to remove it.

In the following section, the three themes are discussed. For each principle, a vignette of an individual child is drawn upon to illustrate the theme in depth. The vignettes were chosen because they resonated with the themes, but there were numerous other examples that could have been chosen, so in that sense they are not distinctive. In addition to the vignettes, data from interviews with staff and a maker are drawn upon in order to examine the principles in greater depth.

Maker agency

On an individual level, the makerspaces studied provided many opportunities for children to explore personal interests and develop skills and knowledge through individual exploration and engagement. There were numerous examples in the MakEY project of ways in which children demonstrated

agency in their immediate environment as a result of their engagement in making. The following vignette focuses on a 3-year-old child in Setting 1, Henry, whose story is told from the perspective of the head teacher, Dana.

> He [Henry] was quite shy, we'd made a referral for him to speech because he wasn't really speaking very much, he was learning four languages, so for us we were kind of thinking, "Do we need any intervention for this little man?" But actually, again, the MakEY project and those activities just captured his imagination, he was thrilled. I remember him making his light box, making his little sticker and putting it on the box, going in the dark den with Jackie and then saying, "Oh Dana, come in, come in," wanting to show me what he'd done … And then the other thing that he did was, when it was group time we talked about what the children had made and kind of showed the other children who had not been involved, and he stood up and he told them about his light and his light box and the traffic lights that he'd made, and … red was for stop and blue was for the police and red was for the fire engine, etc. So all this language suddenly came bursting out of Henry that we'd kind of not really heard before. And then when his mum came at the end of the day he was just like so excited to tell her, to show her his light box, and obviously the dark den had gone by then so he wanted to show his mum his little light show that he'd made. So we went into our sensory room and turned all the lights off and he showed his mum what he'd done. And I talked to her about the PABLO app and she downloaded it instantly on her phone. And she was saying that he actually talked to his grandfather in Lithuania on Skype and was really interested in electric and circuits and things, so she felt that … for him it was just something that had captured his interest and that had actually helped his confidence. And I really couldn't kind of describe his words quick enough, you know, of all the things that Henry was telling us … And then he wasn't around on day two but day three he was there again, and he came in and it had been snowing I think, and he said, "Dana, in the garden, you've got snow," and I could see him looking at the table where you were setting up. And then I remember him going to the table and sitting down and said, "What are we making today?" So you know for me that was just absolutely fantastic … because he was ready and he wanted to see what we were making that day.
>
> (Interview with Dana, 16th April, 2018)

This vignette shows maker agency in operation, in that Henry gained confidence and control through his engagement in the maker project. As he sat down and asked, "What are we making today?", he was demonstrating the development of a maker mind-set, which fostered his active agency. His new confidence impacted not only his expressive language, but also his interactions with others, which was, as noted by the staff, sustained beyond the project. It can be argued that the engagement in makerspaces was conducive to Henry developing *thick agency* (that is, having "varying and dynamic capacities for voluntary and willed actions" (Klocker, 2007, p. 85) because of the way the project enabled expansive learning to take place across and between STEM and other disciplines. The capacity to act independently and with volition in makerspaces can be viewed as constituting maker agency, which may be developed through previous relevant experiences prior to an individual's participating in the makerspace. For those children who have enjoyed tinkering and making in homes and communities, maker agency might offer a platform for a more engaged experience in makerspaces, at least initially. It is of note that in this vignette, Henry's grandfather was already interested in circuits, which may have been a factor in stimulating Henry's interest.

Maker funds of knowledge

At the relational level, there were numerous opportunities for children to draw on their funds of knowledge in their learning with each other. One of the key sources of funds of knowledge that young children in contemporary societies acquire is experience with technologies. Throughout the project, there were many instances when children's prior knowledge of, and experience with, making using technologies meant that they quickly grasped the process involved in a particular maker activity, such as digital animation or photography. They were then able to support the learning of peers through sharing these digital maker funds of knowledge. For example, in Settings 3 and 4, when children had already experienced virtual reality in their homes, they were willing to help other children with the equipment, showing them how to put on the headsets or use the hand controls. The following vignette of 4-year-old Emily in Setting 2 illustrates how younger children were also able to demonstrate their own maker funds of knowledge:

> Four-year-old Emily had brought her house into nursery, and it was now lit up with the light she had made from the laser-cut stand, copper tape, batteries, and LEDs. We then found some dolls in an area of the nursery, and she played with them in the house. I asked Emily if she would like to make a green-screen film in which the dolls could be seen playing in the house, and she agreed. I showed her how to use the Green Screen by Do Ink app on the tablet, and she engaged confidently with the app, knowing how to capture the first film of the dolls without my support. With my help, she then inserted a still image of her house behind the film, creating what she called her "doll story film."
>
> (Field notes, November 21st, 2017)

Emily later assisted her friend when she had difficulty using the iPad as a camera. Emily, like many of the children, was familiar with touch-screen technology such as smartphones and tablets, and thus the project drew on her extensive knowledge of such technologies and her ability to capture images. In a project that involved a survey of 2,000 parents of children aged under 5 in the United Kingdom, 78% of the children were reported as being able to take a photograph using a tablet, with 47% being able to do this without assistance (Marsh et al., 2015). Using child-centered pedagogical approaches to ECE means that practitioners need to identify and build on the digital skills and funds of knowledge children bring from home. In contrast, numerous studies indicate that many ECE practitioners do not see this as a priority (Kontovourki et al., 2017) and struggle to identify and build on children's interests through their curriculum and pedagogical approaches (Wood et al., in press).

Not all children can draw on the same levels of knowledge, however, given the inequities with regard to the extent to which children access digital technologies in the home (Marsh et al., 2015). The makerspaces enabled children who had previous experience in this area to share their maker funds of knowledge with others, thus supporting those whose skills were not as well developed. John, the maker who worked with Settings 2 and 3, noted that one child in Setting 2, Carl, brought his prior knowledge to an activity, as " … he was very quick initially at getting involved with these technologies, he was able to wire up the LEDs and to understand how to put them each way round and what have you." When Carl went on to attempt to light up a Christmas tree that he had designed and which had then been laser cut by John, he became frustrated at first, as it did not work, but John helped him to troubleshoot to get it lit. Because of his confidence in the task, Carl went on not just to help other children, but also adults:

> I could see that he was already very good at actually physically following the instructions and putting the things together in the configuration that we'd specified, and that was one of the reasons why he'd thrived so early in the process. But the moment that he actually got the testing and he saw that, not only did he then about 45 seconds later complete his Christmas tree and what have you, but also immediately then he moved on to helping other children. And I thought that was really interesting. And he actually ended up helping some adults, which I thought was really interesting.
>
> (Interview with the maker, John, 6th May, 2018)

This indicates that makerspaces offer a means of building on young children's maker funds of knowledge in order to engage and motivate them in learning, and, in particular, makerspaces that engage children in the use of digital technologies can lead to them sharing that knowledge with each other in the development of digital communities of practice, thus demonstrating relational agency (Edwards, 2005). Throughout the interviews with practitioners, numerous comments were made about the children's propensity to help each other out and share expertize in the makerspaces. Regardless of these benefits and potential for learning Wood et al. (in press) identify multiple challenges faced by ECE practitioners: digital technologies are not well understood or might not be valued in ways that will advance children's competences or connect with curriculum content, and they might face competing demands from statutory curriculum frameworks that prioritize "basic skills" and school readiness. One way in which these challenges may be addressed could be through the introduction of makerspaces, which can offer a means of blending the digital and nondigital in near-seamless ways, as is outlined in the next section.

Postdigital maker play

Although play was significant for all early years settings that participated in the MakEY project, it was evident that the nature of play is changing in a world in which technology is ubiquitous. Fleer (2017) has argued that technologies are changing the conditions for play, and, consistent with the concept of postdigital play (Jayemanne et al., 2016), the MakEY project indicated children's initiative, competence, and confidence with those technologies. Throughout the MakEY project, children moved across digital and nondigital domains in their play with materials. The semiotic material they were engaged with underwent a process of transduction (Kress, 1997) as it moved from one mode or media to another. This process of *transmodal redesign* (Mavers, 2011) was an essential element of the MakEY project. In addition to movement across modes, there was also movement across media and technologies, from nondigital to digital, and across online and offline domains. The following vignette offers an account of this kind of postdigital play in Setting 1:

> Lena took a long time making her torch (flashlight), carefully wrapping the *washi* tape around it to decorate it. The process of inserting the LED proved to be rather fiddly, but she managed it with Amy's [the artist] support. Lena then entered the blackout tent, where a researcher introduced children to the PABLO app on a smartphone. This enabled children to create slideshows with their torches. Lena spent a long time playing with the torch and the PABLO app in the tent, enjoying seeing the light from her torch transformed on the screen on the phone. At one point, children sang "Twinkle, Twinkle, Little Star" as they played with the torches in the dark, cave-like environment. After creating her light show, Lena watched as her image was printed out on the HP Sprocket printer. She chose to wear the image sticker as a badge on her chest and proudly wore it throughout the morning.
>
> (Filed notes, Thursday 7th December, 2017)

From contemporary sociocultural perspectives, Lena drew on prior knowledge and experience and was supported in this social situation for development by her engagement with the tools (battery packs, LEDs, smartphone, and printer) and the artist. Thus the tools, the environment, the social interactions, and Lena's motivation combined dynamically within a learning leading development orientation. Lena's movement across digital and nondigital, online and offline modes was fluid and spontaneous. For Lena, the wearing of her digital light play as a sticker was just one element of a long series of activities that moved across digital and nondigital domains, but it was obviously one of the more pleasurable elements that led to sustained engagement in the makerspace. This was also the case in Setting 3, when children created clay model Moomins and then transformed them into 3-D digital representations of the models, which they printed on a 3-D printer and used in green-screen animations of the clay and plastic figures (see Figure 1). The children moved fluidly across the

Figure 1. Creating a green-screen animated film with clay and 3-D printed Moomins.

digital and nondigital boundaries, enjoying play with both the physical figures and their digital representations.

At an institutional level, practitioners need to be committed to the provision of a postdigital maker play environment if children are going to be able to engage in playful activities in ways that replicate their experiences within and beyond early years settings. These recommendations are consistent with the argument proposed by Wood et al. (in press) that practitioners need to shift pedagogically from what is developmentally appropriate, to what is developmentally possible. Makerspaces can offer a means of introducing postdigital approaches into established cultural practices, thus shaping children's experiences in ECE in ways that will prepare them sufficiently well for the next phases of education and their postdigital futures.

Conclusion

This paper makes an original contribution to the field in its theorization of the ways in which makerspaces in early childhood settings can facilitate development across all three of Rogoff's (2003) planes of analysis through the fostering of maker agency, maker funds of knowledge, and postdigital maker play.

At the personal level, makerspaces can foster children's agency and provide them with opportunities to explore personal interests. Certain conditions need to be in place for this to happen, of course. If maker activities are too narrowly defined, or adult led, then opportunities for agentic action are closed down (Marsh, Arnseth, & Kumpulainen, 2018). Therefore, open-ended, exploratory inquiries are more conducive to fostering maker agency. At the relational level, children bring their funds of knowledge (Moll et al., 1992) to the site of learning and share them with others in order to support their learning. In makerspaces, children have opportunities to draw on their maker funds of knowledge, developed through their wide-ranging creative experiences with digital technologies in the home. Finally, at the institutional level, makerspaces can enable play to take place across digital/nondigital, online/offline domains if practitioners provide the necessary conditions for this. Postdigital maker play takes place when practitioners recognize that traditional and digital play coexist and that the latter does not displace the former as children continue to engage in multimodal ways with the tools and materials in the setting. This recognition has to take place at the institutional level if children are to be provided with the tools that will enable them to play in ways that reflect their out-of-school lives in a digital age. This paper, thus, explains how Rogoff's (2003) three planes of analysis operate in relation to makerspaces in ECE and introduces theoretical concepts that are of value in understanding how young children learn, develop, and thrive in such spaces.

There are a number of limitations to the study that need to be considered. Firstly, the study focused on children's experiences in ECE settings. In future studies, it would be of value to trace children's maker practices across home and school contexts in relation to the concepts explored in this paper and to explore the extent to which agentic practices cross these boundaries. Secondly, this paper has focused only on ECE settings that are state maintained, yet many children attend private provision, and so the differences between these two domains need to be explored in future studies. Thirdly, the study centered on the provision of pop-up makerspaces inside ECE settings. While the nursery schools involved extended this provision so that they offered makerspaces in the outdoor areas, these were not studied and thus this remain a potential focus for future research, given the different affordances of outdoor areas.

Despite these limitations, we suggest that this paper offers a significant contribution to knowledge. It furthers understanding of the ways in which makerspaces can enhance young children's development across personal, relational, and institutional planes. Through the examination of the concepts of maker agency, maker funds of knowledge, and postdigital maker play, the analysis points to the importance of makerspaces in moving early years practice on to ensure that children develop the dispositions and skills required for 21st century leisure, culture, and employment.

There are numerous implications of this analysis for future research, policy, and practice. In relation to research, this paper indicates that contemporary interpretations of sociocultural theories are of value in considering young children's practices in ECE makerspaces, and there is potential to develop this area further in relation to both curriculum and pedagogy. In addition, there is a need to conduct further studies into practitioners' pedagogical approaches in structuring playful learning opportunities in makerspaces in order to embed the principles identified above. Given the positive experience in MakEY of professionals from a range of sectors across multiple countries collaborating to share expertize (see Blum-Ross et al., in press), it is recommended that such research be inter-sector and international as well as interdisciplinary in nature.

Policy in ECE poses more complex challenges, especially as many countries move toward curriculum frameworks that incorporate defined goals and outcomes, with varying degrees of control of curriculum content (Wood & Hedges, 2016). In the MakEY project, there were differences across countries in terms of the affordances of early years policies for the accommodation of makerspaces. For example, Finland has launched a new curriculum which celebrates and fosters a multiliteracies approach, and makerspaces are key features of many kindergarten settings. In contrast, ECE policy in England has narrowed the curriculum to focus on the "basics," with an emphasis on reading, writing and phonics, and limited expectations for children's selection and use of technology. Other countries involved in MakEY range across the spectrum. In global contexts, policy development needs to be a multifaceted process; within nation-states, local activity and lobbying should take place at the same time as international collaboration, the latter of which can identify best practices and locate them within international ECE discourses of effectiveness and future-oriented curricula.

Finally, in terms of practice, this study indicates that makerspaces have an important role to play in the early years in that they foster learning and development in disciplines that will be of increasing importance to society in the years ahead when areas such as digital fabrication, robotics, and AI will be key to economic success and the development of societies. Embedding approaches that foster maker agency, that draw on children's maker knowledge developed in homes, and that allow them to engage in postdigital maker play can lead to the kinds of learning that will position children as active participants in, and future leaders of, the digital age.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the European Commission Horizon 2020 Programme (H2020-EU 1.3.3) under Grant: 734720.

ORCID

Jackie Marsh http://orcid.org/0000-0001-6192-6198
Liz Chesworth http://orcid.org/0000-0003-0576-0650

References

Arnott, L. (2016). An ecological exploration of young children's digital play: Framing children's social experiences with technologies in early childhood. *Early Years*, *36*(1), 271–288. doi:10.1080/09575146.2016.1181049

Berry, D. M., & Dieter, M. (2015). Thinking postdigital aesthetics: Art, computation and design. In D. Berry & M. Dieter (Eds.), *Postdigital aesthetics: Art, computation and design* (pp. 1–11). Basingstoke, England: Palgrave Macmillan.

Blum-Ross, A., Kumpulainen, K., & Marsh, J. (Eds.). (in press). *Enhancing digital literacy and creativity: Makerspaces in the early years*. London, England: Routledge.

Brahms, L., & Crowley, K. (2016). Learning to make in the museum: The role of maker educators. In K. Peppler, E. R. Halverson, & Y. Kafai (Eds.), *Makeology: Makerspaces as learning environments* (Vol. 1, pp. 15–29). New York, NY: Routledge.

Brahms, L., & Werner, J. (2013). Designing makerspaces for family learning in museums and science centers. In M. Honey & D. E. Kanter (Eds.), *Design, make, play: Growing the next generation of STEM innovators* (pp. 71–94). New York, NY: Routledge.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(3), 77–101. doi:10.1191/1478088706qp063oa

Cannella, G. (1997). *Deconstructing early childhood education: Social justice and revolution*. New York, NY: Peter Lang.

Chaudron, S., Beutel, M. E., Černikova, M., Donoso, V., Dreier, M., Fletcher-Watson, B., & Wölfling, K. (2015). *Young children (0-8) and digital technology: A qualitative exploratory study across seven countries* (Joint Research Centre, European Commission Technical Report No. EUR 27052). Retrieved from http://publications.jrc.ec.europa.eu/repository/handle/JRC93239

Chesworth, E. A. (2016). A funds of knowledge approach to examining play interests: Listening to children's and parents' perspectives. *International Journal of Early Years Education*, *24*(3), 294–308. doi:10.1080/09669760.2016.1188370

Chesworth, E. A. (2018). Theorising young children's interests: Making connections and in-the-moment happenings. *Learning, Culture and Social Interaction*. doi:10.1016/j.lcsi.2018.11.010

Cramer, F. (2015). What is "postdigital"? In D. M. Berry & M. Dieter (Eds.), *Postdigital aesthetics: Art, computation and design* (pp. 12–26). London, England: Palgrave Macmillan.

Daniels, H. (2016). *Vygotsky and pedagogy*. London, England: Routledge.

Edwards, A. (2005). Relational agency: Learning to be a resourceful practitioner. *International Journal of Educational Research*, *43*(3), 168–182. doi:10.1016/j.ijer.2006.06.010

Fleer, M. (2017). Digital role-play: The changing conditions of children's play in preschool settings. *Mind, Culture, and Activity*, *24*(1), 3–17. doi:10.1080/10749039.2016.1247456

Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, *84*(4), 495–504. doi:10.17763/haer.84.4.34j1g68140382063

Hedges, H., & Cooper, M. (2016). Inquiring minds: Theorizing children's interests. *Journal of Curriculum Studies*, *48*(3), 303–322. doi:10.1080/00220272.2015.1109711

Hedges, H., Cullen, J., & Jordan, B. (2011). Early years curriculum: Funds of knowledge as a conceptual framework for children's interests. *Journal of Curriculum Studies*, *43*(2), 185–205. doi:10.1080/00220272.2010.511275

Hsu, Y.-C., Baldwin, S., & Ching, Y. H. (2017). Learning through making and maker education. *TechTrends*, *61*(6), 589–594. doi:10.1007/s11528-017-0172-6

Jandrić, P., Knox, J., Besley, T., Ryberg, T., Suoranta, J., & Hayes, S. (2018). Postdigital science and education. *Educational Philosophy and Theory*, *50*(10), 893–899. doi:10.1080/00131857.2018.1454000

Jayemanne, D., Apperley, T., & Nansen, B. (2016). Postdigital play and the aesthetics of recruitment. *Transactions of the Digital Games Research Association*, *2*(3), 145–172. Retrieved from http://todigra.org

Klocker, N. (2007). An example of "thin" agency: Child domestic workers in Tanzania. In R. Panelli, S. Punch, & E. Robson (Eds.), *Global perspectives on rural childhood and youth* (pp. 83–94). New York, NY: Routledge.

Kontovourki, S., Garoufallou, E., Ivarsson, L., Klein, M., Korkeamaki, R. L., Koutsomiha, D., … Virkus, S. (2017). *Digital literacy in the early years: Practices in formal settings, teacher education, and the role of informal learning spaces: A review of the literature* (COST Report No. IS1410). Retrieved from COST website: http://digilitey.eu/wp-content/uploads/2017/01/WG2-LR-March-2017-v2.pdf

Kress, G. (1997). *Before writing: Rethinking the paths to literacy*. London, England: Routledge.

Langford, R. (2010). Critiquing child-centred pedagogy to bring children and early childhood educators into the centre of a democratic pedagogy. *Contemporary Issues in Early Childhood*, *11*(1), 113–127. doi:10.2304/ciec.2010.11.1.113

Litts, B. K. (2015). *Making learning: Makerspaces as learning environments* (Doctoral dissertation). University of Wisconsin: Madison, USA. Retrieved from http://www.informalscience.org/sites/default/files/Litts_2015_Dissertation_Published.pdf

Marsh, J. (2017). The internet of toys: A posthuman and multimodal analysis of connected play. *Teachers College Record*, *119*(12), 1–32.

Marsh, J., Arnseth, H. C., & Kumpulainen, K. (2018). Maker literacies and maker citizenship in the MakEY (Makerspaces in the early years) project. *Multimodal Technologies and Interaction*, *2*(3), 50. Retrieved from https://www.mdpi.com/2414-4088/2/3/50

Marsh, J., & Bishop, J. C. (2014). *Changing play: Play, media and commercial culture from the 1950s to the present day*. Maidenhead, England: Open University Press.

Marsh, J., Kumpulainen, K., Nisha, B., Velicu, A., Blum-Ross, A., Hyatt, D., … Thorsteinsson, G. (2017). *Makerspaces in the early years: A literature review*. MakEY Project. University of Sheffield. Retrieved from http://makeyproject.eu/wp-content/uploads/2017/02/Makey_Literature_Review.pdf

Marsh, J., Plowman, L., Yamada-Rice, D., Bishop, J., Lahmar, J., & Scott, F. (2018). Play and creativity in young children's use of apps. *British Journal of Educational Technology*, *49*(5), 879–882. doi:10.1111/bjet.12622

Marsh, J., Plowman, L., Yamada-Rice, D., Bishop, J. C., Lahmar, J., Scott, F., … Winter, P. (2015). *Exploring play and creativity in pre-schoolers' use of apps: Final project report*. Retrieved from Technology and Play website: http://www.techandplay.org/reports/TAP_Final_Report.pdf

Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research*, *5*(1), 30–39. doi:10.7771/2157-9288.1099

Martinez, S. L., & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.

Mavers, D. (2011). *Children's drawing and writing: The remarkable in the unremarkable*. New York, NY: Routledge.

Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching using a qualitative approach to connect homes and classrooms. *Theory into Practice*, *31*(2), 132–141. doi:10.1080/00405849209543534

Peppler, K., Halverson, E., & Kafai, Y. (Eds.). (2016). *Makeology: Makerspaces as learning environments* (Vols. 1–2). New York, NY: Routledge.

Piaget, J. (1953). *Origins of intelligence in the child*. London, England: Routledge & Kegan Paul. (Original work published 1936).

Pramling-Samuelsson, I., & Fleer, M. (Eds.). (2009). *Play and learning in early childhood settings*. Basel, Switzerland: Springer.

Ringsmose, C., & Kragh-Müller, G. (2017). *Nordic social pedagogical approach to early years*. Basel, Switzerland: Springer.

Rogoff, B. (2003). *The cultural nature of human development*. Oxford, England: Oxford University Press.

Schwab, K. (2016). *The fourth industrial revolution*. New York, NY: Crown Business.

Sefton-Green, J., Marsh, J., Erstad, O., & Flewitt, R. (2016). *Establishing a research Agenda for the digital literacy practices of young children: A white paper for COST action IS1410*. Retrieved from http://digilitey.eu/wp-content/uploads/2015/09/DigiLitEYWP.pdf

Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative study of three makerspaces. *Harvard Educational Review*, *84*(4), 505–531. doi:10.17763/haer.84.4.brr34733723j648u

Vasilis, N., Vasilis, K., & Wolfgang, D. (2017). Making in the smart city: The emergence of makerspaces. *Telematics and Informatics*, *34*(2017), 1143–1152. doi:10.1016/j.tele.2017.05.004

Vygotsky, L. (1978). *Mind in society* (M. Cole, Trans.). Cambridge, MA: Harvard University Press.

Whyte, J. (2016). Makerspaces in libraries: Play, discovery, and collegiality. *The iJournal*, *2*(1). Retrieved from http://theijournal.ca/index.php/ijournal/article/view/27535/20297

Wohlwend, K. E., & Peppler, K. A. (2015). All rigour and no play is no way to improve learning. *Kappan*, *96*(8), 22–26. doi:10.1177/0031721715583957

Wohlwend, K. E., Peppler, K. A., & Keune, A. (2016). Design playshop: Preschoolers making, playing and learning with Squishy circuits. In K. A. Peppler, Y. B. Kafai, & E. R. Halverson (Eds.), *Makeology: Makers as learners*. New York, NY: Routledge. 1, 83-96.

Wood, E. (2013). *Play, learning and the early childhood curriculum*. London, UK: Sage.

Wood, E., & Hedges, H. (2016). Curriculum in early childhood education: Asking critical questions about content, coherence and control. *The Curriculum Journal*, *27*(3), 387–405. doi:10.1080/09585176.2015.1129981

Wood, E., Nuttall, J., Edwards, S., & Grieshaber, S. (in press). Young children's digital play in early childhood settings: Curriculum, pedagogy and teachers' knowledge. In O. Erstad, R. Flewitt, B. Kümmerling-Meibauer, & I. Pereira (Eds.), *Routledge handbook of digital literacies in early childhood* (pp. 214–226). New York and Abingdon, USA: Routledge.

Yelland, N., & Arvantis, E. (2018). Transformative pedagogies in early childhood education. *Global Studies of Childhood*, *8*(2), 111–113. doi:10.1177/1463949117734979

Zosh, J. M., Fisher, K., Golinkoff, R. M., & Hirsh-Pasek, K. (2013). The ultimate block party: Bridging the science of learning and the importance of play. In M. Honey & D. Kanter (Eds.), *Design, make and play* (pp. 95–118). London, England: Routledge.