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Play as a pedagogical vehicle for supporting gender inclusive engagement in informal STEM education

Elizabeth A.C.Rushton[a *] and Heather King[b]

[a*] *School of Education, Communication and Society, King's College London, London, UK; Orcid ID: 0000-0002-6981-8797 @RushtonDr*

[b] *School of Education, Communication and Society, King's College London, London, UK; Orcid ID: 0000-0002-2849-9398*

School of Education, Communication and Society, Waterloo Bridge Wing, Franklin Wilkins Building, King's College London, SE1 9HN, UK. elizabeth.rushton@kcl.ac.uk

Elizabeth A.C. Rushton has worked within education as a high school teacher, as Director of Evaluation for an education charity that supports school student participation in STEM research and is currently a Lecturer in Geography Education at King's College London. Her research considers young people's experience of science in formal and informal settings and teacher professional development through collaborations with researchers and mentoring school student research.

Heather King is Reader in Science Education at King's College London. She has long been involved in researching teaching and learning in out-of-school settings such as museums and galleries. Her most recent work has involved longitudinal studies of secondary science classrooms with the aim of better understanding equitable practice and supporting more young people feel able to engage in STEM.

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Out-of-school making and engineering programmes that are frequently positioned as playful have increased dramatically in recent years – but how appropriate is the framing of play for engagement in these informal STEM (science, technology, engineering and mathematics) spaces? Drawing on data from two research sites located in the UK, including observations of making and engineering activities with children aged 5-13 years, and interviews with nine key informants, we identify that play has three key affordances namely: (1) play can provide structure, (2) play is considered to be synonymous with open-ended science inquiry, and, (3) play can enable gender inclusive STEM spaces through promoting free-choice. We also note that overly simplistic framings of play may limit recognition by both adults and children of the educational value of these spaces and deny a fuller understanding of the opportunities that such spaces afford in providing children with moreopportunities to engage with STEM, particularly engineering. We suggest that play has an important pedagogical role in informal STEM activities, including making, when it is grounded in free-choice exploration and imagination. We argue for continued discussion and reflection upon both the value of play as a pedagogical vehicle and its affordances for enhancing youth engagement in STEM spaces.

Keywords: play; making; makerspaces; engineering; STEM; gender inclusive engagement

1.0 Introduction

Making activities are becoming an increasingly familiar part of the informal educational landscape, with makerspaces located in science centres, museums and public libraries. Examples in the UK include *The Making Studios* at the Life Science Centre, Newcastle, and *Fab Lab Devon* in Exeter Library, Devon. In the US, prominent spaces include the *Tinkering Studio* at the Exploratorium in San Francisco, *Ingenuity Lab* at the Lawrence Hall of Science in Berkeley, *Maker Space* at New York Hall of Science, and *MAKEShop* at Children's Museum of Pittsburgh. Concurrently, considerable efforts are being directed towards better understanding how to create spaces, including those in out-of-school settings, in which the widest diversity of children and young people feel that STEM (science, technology, engineering and mathematics) is 'for them' (Archer et al., 2015; Dawson, 2014). A common presumption is that such informal activities, will

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offer a ‘playful’ and/or ‘fun’ way to engage with aspects of science and engineering. Indeed, the descriptions of many making activities that we have searched for online frequently include the terms ‘play’ and ‘fun’. But to what extent are such descriptors well-founded? Moerover, are such framings pertinent to the learning that potentially occurs in such spaces? Asking these questions is timely as, despite their growing popularity with young people, parents, schools, policy makers and governments Martin et al., 2018), making activities and approaches are notably under-researched and under-theorized (Nugent et al., 2019). We explore (and reflect on) the ways in which play is understood, implemented and operationalised in STEM focused making activities. Drawing on two research sites which predominantly work with children aged 5 – 13 years old, we consider the practice of, (1) a makerspace, with an implicit emphasis on science and technology through making activities and, (2) a charitable trust, with an explicit emphasis on engineering skills and the value of engineering.

Using Reflexive Thematic Analysis (RTA), we explore articulations of play as expressed in interviews with staff working in makerspaces (and related settings) and in our observations and field notes of activities in these same spaces, gathered over six months, drawn from two case studies located in England, UK. We contend that RTA offers a particularly insightful way of understanding the situation in informal settings as it supports a dynamic dialogue between researcher, key informant and theory. Our research questions are:

(1) How do staff articulate play (explicitly in interviews; implicitly in their observed facilitation and activity design) with reference to STEM focused making activities with children aged 5-13 years?

(2) What are the affordances, or otherwise, of framing STEM focused making spaces as play?

2.0 Making and makerspaces

Making activities have been variously defined in the literature. Honey and Kanter (2013) highlight their hands-on nature and their collaborative iterative approach to learning. Blikstein (2013), meanwhile, references the role played by technologies and materials in making endeavours. Calabrese Barton and colleagues' (2017) definition draws attention to elements of collaboration and creativity in the making process. Martin (2015) offers a working definition of making as:

> '…a class of activities focused on designing, building, modifying and/or repurposing material objects, for playful or useful ends, oriented toward making a 'product' of some sort that can be used, interacted with or demonstrated' (p. 31).

People who participate in making often self-identify as 'makers': the places in which makers come together to engage in making thus become makerspaces.

In describing informal makerspaces, many (Brahms & Crowley, 2016; Calabrese Barton et al., 2017; Honey & Kanter, 2013; Martin, 2015; Sheridan et al., 2014) have argued that such spaces have the potential for greater gender inclusivity in the context of youth engagement in STEM education. This potential is particularly significant given wider research findings which document the persistent under-representation of women within the STEM workforce and engaged in STEM study (Archer et al., 2013). Others, however, have questioned the notion that makerspaces support gender inclusive engagement. Martin et al., (2018), for example, have highlighted making's 'equity problem' (p.36), arguing that whilst making and makerspaces are frequently described as open to all, in reality, they are far from representative spaces for girls and women.

Researchers have also noted that a deep and full understanding of the potential of makerspaces for STEM engagement is currently limited, as an established body of research and theory has yet to develop (King & Rushton, in press). Through this study, we seek to contribute to emergent theorisations pertaining to makerspace practice and pedagogy. The conceptual grounding for our research builds on descriptions and definitions of play from both the wider education literature and studies which specifically consider play in the context of making (e.g. Martin, 2015).

2.1: Describing and defining children's play

Play has long been recognised as central to the development of children (Piaget, 1945; Vygotsky, 1978) and yet no single definition abounds. Sheridan (1977) suggests a broad definition of play, where children have eager engagement in pleasurable physical or mental effort to obtain emotional satisfaction. In contrast, Krasnor and Pepler (1980) offer a more tightly framed definition and argue that an activity constitutes play when five elements are present: (1) voluntary participation, (2) enjoyment, (3) intrinsic motivation, (4) pretense and, (5) where process is more important than the outcome. The elements of open-ended activity, spontaneity and free choice are present in more recent understandings of play, including Mathieson (2017), who describes play as 'activity, motivation and emotional response specifically including freedom to choose' (p. 602). Howard (2017) identifies two difficulties with understandings of play. Firstly, that dictionary definitions of play that include elements of frivolity and fun are at odds with the seriousness that is often apparent in children's play, and secondly, that the characteristics identified as essential to play (e.g. those of Krasnor & Pepler, 1980) are not necessarily visible to adults when observing children at play. Playful learning environments have been defined as those environments which encourage experimentation. This is important, it is argued, as experimentation is necessary to develop knowledge that can be successfully transferred from one context to another (Hatano & Inagaki, 1986). For some authors, the concept of fun forms an aspect or feature of play. For example, Sutton-Smith (2011) describes play as a voluntary activity that includes fun, excitement, free-choice and is intrinsically motivated.

Drawing on diverse understandings of play from the literature, play, at its very least, can be understood as an experience that is open-ended and includes free choice, enjoyment and experimentation. Having explored broad understandings of play, we now consider play in the specific context of making activities including those with a STEM-focus.

2.2 Play in the context of making

The features of the 'maker mindset' are described by Martin (2015) as: 'playful'; 'asset- and growth-oriented' – makers focus on skills that can be developed, rather than fixed abilities; 'failure-positive' – failure is valued as a part of successful making and, 'collaborative' (p.35). Martin (2015) further argues for the educational value of 'experimental play' through making and asserts that 'play, fun and interest are at the *heart* of making' (p. 25, our italics) .

By contrast, notions of play or fun are *not* explicit in the seven core learning practices associated with the maker community identified by Brahms and Crowley (2016). In their content analysis of three volumes of *MAKE Magazine*, including 162 separate articles, Brahms and Crowley (2016) noted the following practices: explore and question; tinker, test and iterate; seek out resources; hack and repurpose; combine and complexify; customize; and, share (2016 p. 3). Moreover, when researchers do use the terms 'play' and 'fun' in relation to making, they frequently use narrow or qualified

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definitions. . For example, Calabrese Barton et al. (2017) describe young people's sustained engagement in maker projects over the course of at least 12 months as being punctuated by 'purposeful playfulness', where young people 'played around with new tools and new ideas' (p. 29). Similarly, Blikstein and Worsley (2016) qualify their use of the term 'fun', arguing that makerspaces should be enjoyable but should never be "*easy*' fun, devoid of frustration or difficulty' (p. 68). Clearly, there is some ambiguity in the use of the term play within both the wider literature that seeks to define and describe play, as well as literature that considers informal STEM activities such as making. Nonetheless, we contend that notions of play and playful learning environments provide a useful and rich conceptual lens through which to explore making and engineering activities with children.

3.0 Methods

Here we describe our research sites, data collection methods and participants before outlining the analytical process used in this study.

3.1 The research sites

Data for this study was gathered from two research sites which are described using the pseudonyms (1) 'making club' and (2) 'engineering club'. The 'making club' is a social enterprise supported makerspace located in London, which aims to provide children with 'greater opportunities to be imaginative and creative' and views such practices as a 'vital part of both a child's development, and a fundamental part of their learning'. Examples of making activities (also called 'makes') that provided an introduction to using code and programming software include, creating a small moving insect or 'jitterbug' from a CD, a battery powered motor and craft materials (e.g. feathers, pipe cleaners, sequins), or constructing vehicles made out of Lego and a motor to race or

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display as part of a 'parade'. Activities may be delivered as part of school workshops, family activities, holiday club sessions and community events that last between a few hours or whole-day events. Sessions are predominantly provided free of charge to participants whilst those for which participants are required to pay are either very low cost (e.g., family drop-in sessions) or include free places for those from low-income groups (e.g., holiday club sessions).

The 'engineering club' is a charitable trust, located in the South of England, whose aim is to engage children, and their families, in engineering through activities that are described as 'learning through play' and, 'both fun and educational'. The education programmes include making activities with an engineering focus, as part of school workshops,and, bespoke actor-led sessions that are located in range of heritage sites e.g. castles, cathedrals and town halls. Examples of activities include building bridges and structures of different types (e.g. arch, beam, truss) and sizes, using a range of materials (e.g. wooden and K'nex blocks,) and engineering focused imaginative play using health and safely themed dressing-up clothes (e.g. high-visibility jackets, hard hats and steel toe-capped boots) and equipment (e.g. eye googles, face mask). All activities and resources are provided free of charge and small grants are also made to fund travel to events or the development of projects in schools and other community groups.

3.2 Data collection

Our data derives from two sources: (1) observations and field notes; and, (2) semi-structured interviews with nine key informants.

Prior to the collection of data, we developed and agreed observation and interview schedules. Our observations took place over 45 hours between April – October 2019 and involved observing a range of one-off facilitated making activities with children, with approximately 30 hours of observations hours located in the making club and the remaining 15 hours in the engineering club. During each activity, we remained on the edge of the learning space and took field notes by hand. At the regular points during observations we discussed our notes to share ideas and perspectives and completed initial reflections.

We conducted nine semi-structured interviews with key informants recruited from the two research sites, six females and three males (Table 1).

[Insert Table 1 about here]

These key informants were identified through and recruited from the two research sites to gather a detailed understanding of STEM focused making in informal spaces. The key informants occupied positions ‘inside’ the STEM focussed making communities and as such, were members of the communities of practice about which they were speaking. This contrasted with our position as ‘external’ researchers seeking to understand the pedagogy of making and the practices of makerspaces. The accounts shared by key informants reflected their various positions as activity designers or facilitators within the research sites and their roles (current or prior) beyond these spaces (Table 1). The discourse on which they drew overlapped across these different positions that were situated in both personal and professional domains.

During the interviews, each lasting approximately 30-40 minutes, informants were asked questions in four main areas: *background* information, including information about their background in making and engineering, and work with children; the making and engineering *activities* that they designed and/or facilitated; the *roles* played by adults working in these spaces; and their understanding of the *philosophy* of each research site. At the outset of the interview we discussed issues around anonymity (participant contributions are shared in this research using pseudonyms, with each site

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indicate using the relevant initials, 'EC' or 'MC') and confidentially with participants. The research was approved by the researchers' university Ethics Committee on 01/04/2019..

3.3 Analytical process

Thematic Analysis (TA) is a method for analysing qualitative data that identifies patterned meaning across a dataset. Braun and Clarke's (2006) articulation of the process has been applied to a variety of disciplines and research areas. The technique has recently been further developed as Reflexive Thematic Analysis (RTA) (Braun & Clarke, 2019) and is described as a subjective, organic and reflexive method of data analysis, where researcher subjectivity is understood as a resource, rather than a barrier to knowledge production. In RTA, researchers actively interpret data and create new meaning through systematic phases of research that are iterative and discursive rather than through the rigid application of a coding framework or codebook. These phases include: (1) data familiarisation; (2) coding the data set; (3) generation of initial themes; (4) reviewing themes; (5) defining and naming themes; and, (6) writing up the analytic narrative in the context of the literature (Braun & Clarke, 2006; Clarke et al., 2015). Through these dynamic and reflective processes, researchers generate new patterns of shared meaning founded upon a central concept or understanding (Braun & Clarke, 2019).

Data familiarisation occurred during the data collection period, through discussions of both interview data and during observation sessions and post-observation written reflections. Both researchers wrote individual summaries, reflections and commentaries based upon our field notes and observations within a few days of each period of observation. These notes and reflections enabled us to foreground our own subjectivities, for example, as the mothers of children a similar age to the participants, we documented our responses to what we observed as both researchers and parents; our experiences as parents undoubtedly informed our understandings of parent-child interactions in this space. On one occasion, one of us (first author) attended a making event at the case study site with her children. Through her participation as a parent, she was able to observe her own children's responses to the environment of the makerspace and to the design and facilitation of activities. The first author was arguably better able to draw meaning that was more contextualised from her observed responses of her own children compared to those she had never met.

Steps 2 – 5 of the RTA process involved the researchers meeting, on average, once per week over a six-month period to look for instances of where framings of play were present in the data generated through interview transcripts and fieldnotes. For example, we looked at ways in which making and engineering activities and resources were framed, either implicitly or explicitly as playful and how facilitators' language and approaches enacted these framings. We considered where these framings were integral to spaces and activities and where they were not. Therefore, our analysis was deductive (i.e., directed by existing ideas, in this case the theoretical framings from the wider literature), and latent (i.e., reporting concepts and assumptions underpinning the data) and situated in our familiarity with informal education practice.

4.0 Results and Discussion

In the following section we document, evaluate and reflect upon the affordances of play in STEM focused making and makerspaces in response to our two research questions:

(1) How do staff articulate play with reference to STEM focused making activities with children?

(2) What are the affordances, or otherwise, of framing STEM focused making spaces as play?

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We found that our key informants have varied understandings and articulations concerning the role and value of play. Some key informants thought play was integral, for others, play was found to be a more problematic term. Three discrete conceptions relating to play were evident in the data: (1) play is used to structure making and engineering sessions, (2) play is considered to be synonymous with open-ended science inquiry, and, (3) play can increase gender inclusive participation in STEM spaces through promoting free choice. An overview of our findings and analytical process is provided in Table 2.

[Insert Table 2 near here]

Below, using excerpts from our field notes and intereview data, we discuss each theme in turn.

4.1 Play used to structure making and engineering sessions

By their very nature, the informal activities that we observed as part of the engineering and making clubs had limited structure beyond logistical aspects, such as the length of the session, compared to formal school environments. However, in the absence of an alternative structure, we observed facilitators frequently using play to provide pace or shape to an activity; for example instead of an assessment, play was used as a way to indicate success. In one instance, as part of making club activities with school groups, children worked individually or in pairs to create a robot or animal that moved using a motor. To signal the end of the activity the facilitators organised races or parades of the robots or animals that were watched by the whole group and shared on a large screen. During these activities there was a palpable sense of celebration and excitement, with children intently watching the activity and at times cheering, laughing and punching the air when their animal or robot 'won' the race or parade. Pete (MC) described the purpose behind the inclusion of the race or parade:

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> ‘We want the children to share their creations and ideas with their peers, we want them to see that we all value their efforts, their creativity, that there are lots of ways of responding to the same activity. We do sometimes have more of a ‘show and tell’ discussion, but this can take a lot of time and can mean that not everybody gets to say something, but a parade means that everyone can share in the excitement and the adults can make sure that every creation gets mentioned in the commentary.’ (Pete, MC)

This sense of celebration was also observed at the end of a making activity during the engineering club. Here in our fieldnotes we observed that:

> ‘At the end of the activity, Chloe (EC) invited a teacher to take a photograph of a group of five children (aged 8 and 9 years) next to the bridge they built and then said to the children that they can each use one finger to knock the bridge over after she has counted down from five. The children smiled and laughed and excitedly knocked the bridge down when Chloe reached ‘zero’ and there was a sense of glee spread across the space, with children and adults working in other activities responding with cheers. (EC fieldnotes, 14/10/19)

As these examples demonstrate, play is readily used as as a way of aiding the transition from one activity to another, as well as sharing and celebrating making at different points. Play in this context reflects the definition of play given by Sheridan (1977), as the children’s ‘eager engagement’ in the activities and the emotional satisfaction they derive is clearly observable. Play as defined by Krasnor and Pepler (1980) is also broadly evident in the above observations: children’s enjoyment is discernable and there are elements of pretense, in contexts where process is more important than the outcome.

4.2 Play is considered to be synonymous with open-ended science inquiry

For both the programme designers of the engineering club and the making club, play, and its exploratory open-ended nature, was explicitly articulated as a frame for making activities:

> 'We think that play is part of the process, play is about making sure that children don't have constraints, they spend most of their time at home and school with limits to their playfulness.' (Tim, MC)

As well as affording a significant lack of 'constraint', play is also recognised as supporting unstructured activities that engage children:

> 'Play is used to engage children, the more you can engage the children the better…Allowing children to explore engineering and have conversations about engineering as part of play is more engaging than activities that have a fixed beginning, middle and end.' (Sally, EC)

In encouraging young people, facilitators regularly referred to having fun as synonyms for 'discover', 'experiment', 'make and test', 'learn by doing' and, 'to use your imaginations'. Chloe consciously interchanged comments about having fun with language typical in formal science inquiry:

> 'At the end of the building activity, the teacher asked what they were doing. Chloe replied, 'we were having fun: we had an idea that we wanted to test'. Chloe says to the group, 'what do we call that?', and the group reply in unison, 'a hypothesis!'. Chloe turns to their teacher and says, 'Miss, aren't you impressed with their hard work?' (EC field notes, 3/10/2019)

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In this way, facilitators regularly position playful activities, which children are likely to recognise as familiar and therefore feel at ease, as akin to language of scientific inquiry. Furthermore, in this example, Chloe encourages the children's teacher to acknowledge and validate the children's playful activity as 'science', making explicit the connection between the more familiar informal building task in which the children feel comfortable and bring that confidence to the formal science inquiry they experience in classroom settings.

4.3 Play can increase gender inclusive participation in STEM spaces through promoting free choice

During our observations we noted many instances where play was used to incorporate free choice into sessions so that children did not need to follow a standard formula or process (as in school lessons). For example, as part of the engineering club's activities, children had the opportunity to spend about 20-30 minutes in a small groups with a large box of health and safety clothing for the construction/engineering industry. This included helmets, high visibility jackets and coats, goggles, face masks, gloves and boots. Included in this area was a mannequin, a similar size to the children, dressed in the health and safety clothing, with labels attached that also include information about the clothing's purpose. We noted the following during this activity:

> '…as the children explore the box there is an atmosphere of 'dressing-up', they are relaxed and curious, pulling items out of the box and putting them on. As they do so, they talk to one another and incorporate role play, one boy says as he puts on the ear defenders and the jacket and trousers, 'I can't hear! I am not cold anymore, even though I am building a bridge and it is winter!'. Another boy mimes using a hammer…The boys tap each other's hard hats and smile and laugh. Their teacher takes photos and says, 'wow, you are engineers! Let me take a photo for your mum! It suits you!' (EC field notes, 3/10/2019)

In this activity children are not guided by an adult, they are able to choose the clothing and equipment they do or do not want to wear (for example one girl decides not to wear ear defenders) and they are able to dress up together, exploring the clothing at their own pace, rather than in a guided, sequential activity led by a teacher with one volunteer child demonstrating the clothing to an audience of their peers. Catherine (EC) described how she and Chloe had initially had concerns about including a 'dressing-up activity' in the workshop as they felt that this could have been seen by teachers as having less value compared to the construction-focused activities, but that she wanted to include a range of activities demonstrating different aspects of engineering:

> 'The activity with health and safety clothing, that, we thought, was a bit of a risk, we wanted to included different activities so that children wouldn't get bored doing the same type of thing all morning or afternoon, but also because with dressing up, you don't need adults, you don't need them to explain what to do, or how something works, the children can just look in the box, they can explore health and safety and engineering themselves, they can make choices and decisions, even if these are quite simple choices, they are making them, not their teachers or other adults and that I think this is important, it helps them think for themselves.' (Catherine, EC)

We argue that this framing of free choice promotes more equitable engagement in STEM activities as every child has an opportunity to participate in a way in which they feel comfortable. Furthermore, the nature of the activity, where boys and girls could equally choose to dress-up and act out roles as engineers, created a space where eningeering was not overtly associated with a particular gender and so did not reinforce notions of engineering as either ‘other’ for girls or ‘normal’ for boys. Indeed, all the staff involved in the engineering club were female which further underlined engineering as open to both girls and boys.

At the making club, play and choice were similarly integral to the design of the open-ended, drop-in events. Children were free to choose which activities they wanted to engage in. . The space was divided into a variety of activity areas; one such area included nine child-height Lego tables, with stools and boxes full of assortments of Lego bricks. Children were able to build Lego structures and add them to the collection in a central table. In another area a series of wooden and carboard ramps were set up for children to race Lego vehicles. These ramp races were very open and free, with no adult directing the start of races, or announcing the winner, and children were free to gather up their peer’s discarded vehicles and incorporate them into their own constructions. During one session we observed that:

> ‘Around the ‘race ramps’, children aged 8-12 years play with the vehicles they have created from Lego. Facilitators are present at the edge of this space, and their role appears to be supervisory, encouraging children by suggesting materials they might use, prompting children to work together to build a vehicle and providing a calming presence when children were very excited by the races. The atmosphere is very much child-led, rather than organised or directed by adults. (MC fieldnotes, 20/06/19)

When discussing making activities, Molly (MC) noted that the more open ‘play-type’ activities were important in fostering the engagement of both girls and boys and helping to build their confidence to explore topics in science and engineering with which they previously had limited experience. Molly suggested that children who encountered making through playful approaches, and especially girls, were less likely to worry about mistakes and be more willing to try new ideas because they were part of a 'game' than if they were part of an activity that was more formal. We made the following observation:

> 'Molly is supporting a group of 12 children (three girls and nine boys) aged 8-10 years to create a a moving insect using craft materials and a motor. Children are working together in sub groups of three or four, whilst Molly moves around the room. She notices that the three girls are sitting together quietly and do not appear to be engaged with the making task although one girl, Melody, is drawing. Molly sits at the table with the girls and asks Melody about her drawing. Melody tells her about the drawing which includes a rainbow. Molly praises Melody for her drawing and the other two girls (Jaya and Alice) share that they like rainbows and have seen them recently. Molly asks the girls how they could include a rainbow design in their make, suggesting that the insect could have 'rainbow wings or pattern on their body'. Alice asks Molly about the motor and Molly explains how the motor works and encourages Alice, Jaya and Melody to, 'have a go and see what you think, how could your insect move? Could it be like a spider? Or would it float like a dragonfly? You can try out the motor, have a play, and see what works with your ideas, that is what I try to do when I am not sure where to start'. Once Molly walks away, the girls are much more animated and discuss their ideas, with Alice joining Melody in sketching out ideas for the insect and Jaya goes to another table to gather some red and purple feathers alongside a motor and lego parts so that they can create a rainbow-inspired insect. (MC fieldnotes, 3/06/19)

However, as we discuss in the following section, play was not a term that all facilitators were comfortable using in relation to making and/or engineering activities.

4.4 The contested nature of play as an appropriate framing of STEM focused activities

When discussing the framing of activities in the making club, Ian described how important he thought play and imagination were as part of children's learning. Ian felt that play, and the value of play, had been lost in children's education and needed to be 'brought back'. For Ian, it was important to explicitly articulate making activities held at the makerspace as play, not only because playing or games provided activites that children perceived as 'low risk' but because Ian wanted to foreground play and imagination as important opportunities for children's learning and to share this with children, parents and teachers. As with Ian, Pete (MC) also actively sought to use play as a positive framing for making activities where children needed to use their imaginations. However, although we observed facilitators frequently using play to structure sessions and promote engagement through free choice, unlike Ian and Pete, the framing of play was not universally viewed as appropriate by all facilitators and some suggested that the term play should be avoided, especially in the context of STEM focused activities. For Claire (MC), play was a term she actively avoided using due to a concern that others (who did not work with children) would view playful activities as superficial. Claire argued that, in an effort to make a STEM based activity engaging, there could be an over-reliance on creating a playful activity, rather than sharing the inherent value or interest of the activity itself:

> 'We need to frame the way that children learn and they enjoy science activities. It's about: 'let's do this: this will make you feel really satisfied, and inherently joyful.' It's the science that is fun, not the activity.' (Claire, MC)

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Moreover, when asked what facilitators wanted children to gain from activities, some facilitators took pains to not refer to the terms ‘play’ or ‘having fun’. Rather they referred to experiencing ‘achievement’ and ‘satisfaction’, ‘pride’ and ‘enjoyment’. Jen, (MC) said:

> ‘…we want the kids to experience joy, we want them to love it, but play? I am not sure, I think they need to come to the end of the experience feeling that they have learnt something, they have achieved something and have enjoyed doing it.’ (Jen, MC)

Similarly noting the notion of achievement, Claire additionally commented that “children do not use the word fun to describe their experience, they use the word ‘proud”. Although Sally (EC) acknowledged that she saw play as having a very important role in framing activities and promoting engagement, she advised the engineering club facilitators against explicitly using the term ‘play’ when they ran [bridge building] activities with children. Rather they should use the terms ‘have a go’ and ‘explore’ through ‘hands on’ activities and ‘challenges’, so that the older children (aged over 8 years) did not view them as ‘babyish’. Clearly, there is a widely held concern among the key informants that both adults and older children may not perceive any value in making and/or engineering activities that are explicitly described as play. However, whilst some facilitators responded to this concern by removing or replacing the term ‘play’ or ‘fun’ when describing and implementing activities (e.g. Claire, Jen, Sally) other facilitators (e.g. Ian, Pete) sought to explicitly describe activities as ‘play’ so that the value of play for children’s learning could be shared with parents and teachers.

5.0 Implications

Having explored and reflected upon the ways in which play is made explicit and implicit in making and engineering spaces for children, we note that play is used in different ways to structure activities, as a stand in for science-related tasks, and as a mechanism for ensuring that both girls and boys participate. We also highlight the contested nature of play as an appropriate framing for STEM focused activities, including informal making and engineering activities. We now turn to consider the implications of these findings and how they could inform future research in informal science learning spaces.

Educators and parents have long valued play as a way to create a relaxed learning space that can support free-choice participation which, in turn, can foster more pro-longed engagement with the topic matter. In particular, the informal sector has consistently recognised the role of free choice in promoting engagement and, has sought to create opportunities to incorporate and promote this as part of STEM activities (Falk & Dierking, 2000; Stocklmayer et al., 2010). The dressing-up activity included in the engineering club is one such instance where choice was enabled through play and children had autonomy within the broad framework of the activity. Furthermore, we suggest that the pedagogical vehicle of play can enable and promote pro-STEM attributes such as inquiry, perseverance and creativity. Here we note that such attributes are particularly cited by policy makers keen to develop the STEM workforce (BEIS, 2017; NAO, 2018). Relatedly, research that considers informal science contexts has previously recognised the gendered performativity of science identities, where science identities enacted by boys are privileged over those of girls (Archer et al., 2016; Dawson et al., 2019). Indeed, research from the US (Lewis, 2015; Kim et al., 2018) and the UK (Dawson, 2017; King & Rushton, in press) suggests making and makerspaces

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are faced with a continuing equity issue, with boys being more likely to prosper than girls. Silfver (2018) argues that informal spaces, such as a science centre, can provide a context in which gendered science identities can be challenged and disrupted. Drawing on our findings we suggest that play in the context of making and engineering clubs can promote more equitable engagement, where children encounter science and engineering in a space that is *collaborative* rather than *competitive* and where STEM activities are presented as creative, imaginative and open-ended. These characteristics are less likely to be associated with masculinity, and therefore we argue these spaces are less likely to reproduce the discourse of science and STEM as 'masculine', compared to other spaces of informal science learning (e.g. Nicolaisen & Achiam, 2019).

This current study has underlined the negative associations that some key informants have with the term play: because play is called play, its role as a pedagogical vehicle can be misunderstood by children, parents, teachers and educators as simplistic, superficial, immature and lacking rigour. Previously we have argued (Rushton & King, 2020) that play as part of informal science learning also contains elements of 'challenge', and, that for both younger children (7-11 years) and early adolescents (11-14 years), challenge becomes an important aspect of promoting and sustaining engagement and enjoyment in making activities. Furthermore, we have suggested that challenge, with a focus on perseverance, pride and satisfaction, could be a more appropriate framing for making activities with adolescents (Rushton & King, 2020). In these findings, we broadly concur with Dismore and Bailey (2011), who suggest that the factors that create enjoyment change during childhood development and that as children move through adolescence the fundamental component of enjoyment shifts from 'fun' to that of 'challenge'.

Having furthered our understanding of these spaces through this current research with children involved in making and engineering clubs, we note that children themselves recognised the importance of perseverance and gained pride and satisfaction when they persisted through periods of challenge. Indeed, our findings suggest that several facilitators working in making spaces promote tenacity and achievement as the more valued features of activities and afford play only a secondary role of generic descriptor. However, we maintain that the playful nature of the activities was found to be an primary factor in sustaining children's motivation to engage with science, technology and engineering through making and building activities. Further, we contend that play allowed children the freedom to shape the nature of their participation in an activity, providing a flexible space in which to engage, supported by their friends and, in some cases, their teachers. Thus, we argue that play is key.

The description of 'purposeful playfulness' made by Calabrese Barton and colleagues (2017), acknowledges the ways in which making activities that are creative, personally relevant and playful can support young people to develop STEM knowledge and practice in the context of making. However, we also note that the use of this terminology seeks to qualify play, and arguably shifts the pedagogical value away from a grounding in free-choice, exploration and imagination. We thus urge designers of informal learning spaces and policy makers to be innovative in their consideration of play, and caution them not to dismiss or qualify the value of play, but instead continue to discuss and reflect upon play, and to research its affordances for enhancing youth engagement in STEM, in a variety of contexts including informal spaces.

In our ongoing work we are considering the particular affordances and challenges of implementing play as a pedagogical approach in one-off facilitated STEM activities, in contexts which include museums and science centres. Further research in this area is of particular relevance, as the opportunity to engage young people in STEM is often focused in these serendipitous, one-off encounters between science educators and engagement professionals, and the wider public. The need for this continued research focus was noted by Tim (MC) as he reflected:

> ‘Making activities and initiatives are becoming a lot more common, but we need to ensure that we’re offering as rich an experience as we can. We need to make sure that our activities are enjoyable and valuable, and we need to continue to collaborate with others, including researchers to make sure that our staff are supported to deliver the activies appropriately so that girls and boys want to keep coming back to learn and explore with us.’ (Tim, MC)

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Research Site	Key Informant	Role(s) with the Research Site	Role(s) beyond the Research Site	Demographic Information
Making club (MC)	Claire	Activity designer Facilitator	Formerly primary school teacher	Female, 30-40 years, White Continental European
	Ian	Facilitator	Maker Computer Programmer	Male, 45-50 years, White British
	Jen	Facilitator	Illustrator	Female, 20-25 years, BAME British
	Molly	Activity designer Facilitator	Maker	Female, 30-40 years, South American
	Pete	Activity designer Facilitator	Maker Formerly a primary school teacher	Male, 35-40 years, White British
	Tim	Education programme designer	Public engagement professional	Male, 40-50 years, White British
Engineering club (EC)	Catherine	Facilitator	Formerly secondary school science teacher	Female, 35-45 years, White British
	Chloe	Activity designer Facilitator		
	Sally	Education programme designer	Engineer	Female, 50-60 years, White British

Table 1.1 Key Informants

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Superordinate theme	**Sub-theme**	**Indicative observation and/or interview data**
Play used to structure sessions.	Play enables children to foreground/signal their enjoyment (or otherwise). Play provides an 'ending point' to a session/activity. Play used to indicate success. Play used to share ideas between children and adults.	'…a parade means that everyone can share in the excitement and the adults can make sure that every creation gets mentioned in the commentary.' (Pete, MC) 'At the end of the activity…the children smiled and laughed and excitedly knocked the bridge down…there was a sense of glee spread across the space, with children and adults working in other activities responding with cheers.' (EC fieldnotes, 3/10/19)
Play synonymous with open-ended science inquiry.	Play provides a 'low risk' or 'failure positive' learning environment. Play encourages an exploratory and experimental learning environment. Play encourages collaboration with peers.	Allowing children to explore engineering and have conversations about engineering as part of play is more engaging than activities that have a fixed beginning, middle and end.' (Sally, EC) 'A pair of girls (aged 9 years) road test their animal. They note that it wobbles to the left. They reposition the legs and test it again. It still wobbles. They adjust the head further and test it again.' (MC, fieldnotes 16/04/19)
Play can increase gender inclusive participation in STEM spaces through promoting free choice.	Play includes a variety of activities with different levels of facilitation. Play enables both girls and boys to make decisions and choices about the direction of activities. Play allows both girls and boys to incorporate their ideas and perspectives.	'…the children…can explore…engineering themselves, they can make choices and decisions…I think is important, it helps them think for themselves.' (Catherine, EC) 'Molly encourages a group of three reluctant girls to engage in an activity by suggesting they 'have a play, see what works with your ideas". (MC fieldnotes, 3/5/19)
The contested nature of play as an appropriate framing of STEM focused activities.	Play understood by facilitators as valuable for young people's engagement in STEM activities.	'Play and imagination needs to be brought back into children's experience of education…they promote creativity' (Ian, MC)

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	Play seen as valuable by facilitators for promoting children's creativity and resilience. Facilitators regard play as 'missing' from children's learning experiences. Facilitator perception that other adults (e.g. parents/teachers) will not value activities framed through play. Facilitator perception that older children will view activities framed by play as 'baby-ish'.	'Playing gives the children the chance to use their imaginations and bring their own ideas to the fore.' (Pete, MC) 'If we encourage girls and boys to approach our activities through play they are often more relaxed and self-assured.' (Chloe, EC) 'I am not sure play is a helpful term to use, it could seem superficial to those who don't understand the value of what we do.' (Claire, MC) 'How you describe activities and makes is important…play could seem 'baby-ish' (Jen, MC)

Table 2. Four superordinate themes, with sub-themes and indicative observations and/or interview data.