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ORIGINAL ARTICLES

Crystalising Maker Moments: Postdigital Storying Across Contexts

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Abstract

This paper presents a theoretical conceptualisation of 'postdigital storying' as an emergent pedagogical process of engaging in meaning-making and literacies in educational contexts. In order to highlight the nuanced learning and communication involved in this approach, we examine and discuss three empirical examples of children and teachers working together in classroom makerspaces, drawn from data we gathered during a year-long research project undertaken by the Maker{Futures} team based at the University of Sheffield. Through discussion of these 'moments of making', we develop the metaphor of a crystal to highlight how the multifaceted nature of postdigital storying refracts, reflects or absorbs the light of the digital in myriad ways according to the configurations and qualities of the spatial, temporal, material and social factors. We argue that it is important to 'crystalise' moments of making in this way, by applying postdigital logic, in order that researchers, policy makers and educators may better understand the ways that learning is shaped and facilitated in makerspaces across contexts.

Keywords Makerspaces · Literacies · Classrooms · Design · Making · Storying · Postdigital

> Crystals grew inside rock like arithmetic flowers. They lengthened and spread, added plane to plane in an awed, perfect obedience to an absolute geometry that even stones-maybe only the stones-understood. (Dillard 1987: 139)

Introduction

There has been significant research on the nature and properties of digital literacies in relation to technologies (Lankshear and Knobel 2008; Potter and Gilje 2015; Wohlwend 2020), with less emphasis on ways that students learn alongside

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technologies in physical spaces with material texts. To truly and authentically understand contemporary communication and meaning making, researchers should explore how people experience and interpret their actions within and across technologies which often means being in a physical space with analogue/material texts. This is important because being digital is more than technologies, it is a way of living that is increasingly called postdigital (Bhatt 2023; Gourlay 2023; Knox 2019). As multimodal, makerspace researchers, we have individually and collaboratively documented how children and young people often combine physical non-digital materials like a piece of cardboard with physical digital components like LED lights and micro:chips to make a design. There is no separation here between physical/digital or material/technological, rather this type of composing and making represent ways that children and young people are 'critical agents of technology' (de Roock 2021; Robinson 2022; Vakil and McKinney de Royston 2022: 4). Such a critical approach to understanding pedagogy and storying (the focus of this article) pushes against either a default in education in policy for print-based modes of teaching (Burnett et al. 2014) on the one side, or the market-driven technology-determinist notions that AI platforms and screens should unproblematically move into classrooms as they currently are (Oliver 2011; Selwyn 2016). We are not suggesting that educators are uncritical, rather we highlight how makerspace pedagogies offer a productively disruptive stance within which teachers and children may push back against anachronistic back-to-basics and on technology default perspectives. In this article, we present an alternative perspective which we developed alongside teachers that is about making and to be specific, crystallising ways that students engage in postdigital storying through design as well as other pedagogies. The article explores a year-long knowledge exchange research study on makerspace pedagogies that are a part of teaching in six primary and secondary schools in England.

Postdigital Storying as a Pedagogical Practice

In the article, we adopt the term storying (rather than storytelling or story-making) to describe an emergent pedagogical approach to meaning-making and literacies in educational contexts. In doing so we build on the research of Goouch (2010) who used this term in her description of improvised interactions between teachers and children in early years classrooms. Whilst her focus was on the interpersonal and verbal manifestations of emergent narratives in educational settings, we propose that this might also be extended to consider the role of non-human actors too (such as materials, time and spaces) which influence and affect the events and meaning making that unfold moment-to-moment (Colvert 2022). Goouch's argument that storying possesses a playful quality is one that we also adopt, as well as the importance of human identities and histories in the storying process. Goouch suggests that '[t]he creation of play narratives, or storying, is a way for children to make visible what is in their mind's eye, interweaving the entire range of significant people in their lives and creating complex intertextual narratives, often over time' (2008: 98). However, in this paper, we also suggest that materials and spaces bring their non-human

histories to bear on meaning-making processes. But, why you may ask, is this storying postdigital? Adding a postdigital conceptualisation to storying practices shifts our awareness of the ways that spaces, timescales, materiality, and practices inflect and intersect during meaning making. Indeed, in this article, the point of departure is to reimagine storying practices through a postdigital logic.

A simple definition of postdigital is *more than* digital (Gourlay 2023; Bhatt 2023): more than technologies, more than screens and software, and more than watching and playing multimodal texts of all shapes and sizes. From a pedagogical postdigital perspective, we approach learning with the assumption that the digital or digitality is a lived practice, aligned with postdigital thinkers (Burnett and Merchant 2020; Gourlay 2023; Macgilchrist 2021; Rowsell 2024) who maintain that you cannot be digital without also engaging with matter and physical spaces. Postpandemic, movements across digital-material life has changed in embodied and affective ways (Hollett 2021; Leander and Ehret 2019). Being postdigital means engaging in digital-material mediations and people do not generally separate out these mobilities across physical and visual spaces in the everyday, but instead exist within and across them in a fluid dance (Rowsell 2024). This liminal dance between screens and people needs defining and light cast on the phenomenon in order to understand educational practices. Our argument rests on a contention that innovative teaching and learning should be premised far more on postdigital assumptions, logic and content framing. With a sudden ushering into virtual spaces and digital texts during the pandemic, the world moved in swift order into being digital and sitting in a pool of water that is digital as far as the eye can see and then further still (Rowsell 2024). Postdigitality by its nature is largely digital, but with physical and spatial qualities. Think about posting a live concert you are at on Instagram—you take the shot, then upload it as a story or post with a descriptor or not, and then share it with your Instagram family who are near and far. If you are lucky enough to have Wi-Fi and a phone, these tacit actions happen quite fluidly as you go about your life, but deconstructing this simple moment—there are layers, mobilities, digital-material properties.

In this paper, we spotlight three telling moments of postdigital storying. Postdigital storying is an improvised and affective process in which children and adults intra-act (Barad 2007) in myriad ways with materials, spaces, time in social meaningful literacy practices. These 'maker moments' (Murai et al. 2019) happened during the 2023/2024 school year in primary and secondary schools in England. Six schools took part in a research study over 12 months. All of the participant schools agreed to document and reflect on their making practices in classrooms and help us to evaluate our makerspace programme called Maker{Futures}. Makerspace approaches to learning (Marsh et al. 2017) are an ideal way to frame and inform postdigital meaning-making. Postdigital storying happens on-the-move (Marin et al. 2020) across material-digital texts. Postdigital storying calls on multimodality and design practices with added layers and greater dimensionality than before (Burnett and Merchant 2020; Gourlay 2023). In addition, there is low-tech and high-tech software, tools and technologies available globally which is integral to modern-day storying. What we have observed as makerspace-multimodal researchers are the ways that learning moves fluidly within material and digital practices. This is postdigital storying, and we argue that pedagogy needs to facilitate it.

The Maker{Futures} Maker{Schools} Project

Maker{Futures} is a research and pedagogical programme in the School of Education at the University of Sheffield concerned with the advancement of makerspaces in England within formal and informal educational settings. Makerspace research involves active learning through design and DIY practices where students learn as they make/build. A large strand of this work is the Maker{School} programme, supporting educators to develop maker-based practices and embed maker pedagogies in classroom settings. The research presented in this paper was undertaken by all members of the Maker{Futures} team,[1] alongside the Maker{School} programme, and was funded in part by a UKRI Impact Acceleration Award grant, Extending and Evaluating Maker{School} in UK Primary and Special Education.[2] We worked closely with six partner schools in a knowledge exchange and research capacity, to develop our approaches with teachers, explore the implications of these for teaching and learning, and to measure the impact that our maker pedagogies had on children, teachers, and the wider school community. All schools are located within a city, with four in the North of England, one in the Midlands, and one in the South of England. In each school, we worked closely with a group of teachers and their students from across year groups as well as senior leaders. Over the 2023–2024 school year, schools were visited between 3 and 10 times each by members of the research and Maker{Futures} team. Some schools also took part in several staff training opportunities around maker pedagogies and skills development. In several schools we worked closely with teachers to co-develop new lessons and projects. At each meeting, reflections from teachers were recorded and transcribed. We also visited schools during sessions of making and were able to make observational field notes and create a team private blog on how the children were engaging in the making process and interacting with materials and digital resources. Data collection methods also included questionnaires at the beginning and end of the research study (August 2023 and June 2024). We also interviewed all Head Teachers involved in the research study. There was significant fieldwork in the six schools to document and analyse maker moments and it is this that we focus on in this paper, which is a culmination of our co-research and theorising of postdigitality within the context of storying.

Theory: Facets of Postdigital Storying

But let us step back a moment to reflect upon postdigital storying versus more conventional storying. Postdigital storying is a process which is shaped by a range of entanglements: tangled up networks, platforms, software, technologies, algorithms, and also people as story makers with their agentive interests, physical spaces, and

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analog texts. These jumble and weave together into multimodal designs. A key facet of postdigitality are the new ways and methods for being playful during the process of storying. Gamified platforms like Minecraft are converged, relational and layered storying worlds that give players a freedom to roam, build, and think materially on screens (e.g., mining and breaking bricks in Minecraft). An essential point here is that players are often simultaneously engaging with the materials in a physical space (such as tables and computers) as well as engaging materially in virtual environments combining 'on- and off-screen material elements' (Bailey 2017: 97). That is, games like Minecraft simulate material practices like breaking up a brick. Minecraft scholars like Dezuanni (2020) describe the layered nature of Minecraft worlds. Dezuanni (2020) argues that digital platforms are sites of knowledge development, and this development relies heavily on peer exchanges across platforms. Dezuanni uses the term 'platform' to signal the architectural layering of digital spaces, especially hardware and software that permeate digitality. He maintains that 'peerness' is active in and inherent to digital experiences and, importantly, that this is a good, enjoyable and productive thing for users. Minecraft has the markers of a culture: cultural practices (e.g., fighting zombies), semiotics and multimodality (e.g., specific Minecraft design practices), economics (e.g., capacities to buy and sell things), cultural hubs (e.g., chat, like and dislike functions), politics (e.g., 'the social goods at stake and how they should be distributed' [Dezuanni 2020: 14]). One's sense of belonging is crucial in postdigital cultures and spaces because people will generally keep going back to places that accept and reflect them; places where they can find themselves aesthetically, consciously, and sensorially.

The kind of making and storying featured in the article is inherently posthuman (Barad 2007). What this means is that there is a sense of equality or as posthuman and sociomaterial scholars phrase it (Barad 2007), and flattened ontologies between human and more-than-human properties. Returning to the Minecraft example, a brick and player in the game are on an equal plane of becoming together. Or, to use a makerspace example, a cardboard structure and designer become into a storied multimodal text together—on equal footing (Kuby et al. 2018). This paper therefore adopts a posthuman approach (Kuby and Rowsell 2017) to understanding making in recognising that humans have agency and intentionality when engaging with materials and spaces but that these non-human entities also inflect with and shape the creative process. Barad describes 'the mutual constitution of entangled agencies' (Barad 2007: 33). Intra-actions is a term used by Barad (2007) to describe a process of becoming that takes place between more-than-human/matter and humans as equally agentive in the world. Postdigital storying then is multi-faceted and to understand it we need to attend to materiality, spatiality, temporality, and social practices as other scholars have (Bhatt 2023; Burnett and Merchant 2020; Gourlay 2023), but we combine them all here as our lens to interpret makerspace pedagogies across schooling contexts.

Facet 1: Materiality

Maker moments involve matter and materials combined in ways that are meaningful to designers. Documenting materialities means working with and reflecting on the agency of matter, asking questions like, 'What will the cardboard let me do?', 'How can an LED light enhance my story?', 'How does matter make me feel?' In this way, there is a vibrancy to matter (Bennett 2009). This vibrancy circulates within materials in particular ways and makers gravitate towards them. Based on our observations during this research and other research studies (Rowsell 2011, Rowsell et al. 2017; Rowsell and Shillitoe 2019; Rowsell et al. 2024), designers respond *with* the world through senses and inviting in wonder through our senses. Materiality in a basic sense are the properties of matter/things people use to design and make. Often, when making or designing something, there is a driving idea, story, or objective. For this research, most teachers framed maker moments around a storyline like 'The Perfect Planet' or the Olympics. Stories influence and inform materials chosen to make a design or composition. Stories also emerge through playing with stuff that offer possibilities that composers had not considered before. Kress (1997) described this type of multimodal meaning making as motivated signs—motivated by the identity of makers. Maker moments are emergent and full of possibilities that we as researchers witnessed intermittently.

It is important to attend to the ways in which materials are integral to the meaning-making process and to the potentiality of what emerges or does not emerge during postdigital storying. Importantly, materialities are not only physical properties, but also they can be pixelated materials or materialities in interface or even materialities inside screens (like a motherboard). In this article we will present three maker moments that illustrate how students fluidly combine digitality with matter.

Facet 2: Spatiality

The spaces in which postdigital storying and making take place are not neutral contexts. They actively affect the processes and meaning making that occur. When reflecting on spatiality we might ask ourselves, 'How does the position and accessibility of materials (such as iPads or computers) have an impact on the types of practices and interactions that occur?', 'How does it feel to make in this space?', 'How do I move through and with the space when making?' Soja (2010) suggests three ways of understanding spaces. There is the 'real' and physical space that can be mapped and viewed (the Firstspace) and then there is the imagined space which can be visualised and conceptualised (the Secondspace) and then there is 'a fully lived space, a simultaneously real-and-imagined, actual-and-virtual locus of structured individuality and collective experience and agency' (Soja 2010: 11) (the Thirdspace). Central to this conceptualisation is that spaces are also 'places': imbued with social and cultural meanings that have developed overtime. Digital technology can affect our sense of space and place in myriad ways. Think of the sense of being both in a room and in a virtual world, the affect that augmented reality has on seeing

the digital and physical world overlayered or the way that using face-time seems to bring people closer to us.

Tsing (2015) suggests that young people can move their understanding of *acting with* the environment to *acting upon* their environment within meaning making practices. She introduced the notion of 'act with noticing' that moves beyond physically working with people and matter to explore enmeshed connections across things/matter and people. Her framework goes deeper into the entanglements that happen naturally as humans interact and intra-act across contexts and environments. There is never one interpretation of acting-with, but instead endlessly different ways to intra-act and become with environments. Think about walking in a nearby park or green space and petting a dog or touching a tree as you make your way along a path. These tacit, naturalised ways of being, behaving and performing in nature and environments can also inflect with making practices. Over recent years a strand of literacy research has emerged which 'foregrounds place and space as constitutive, rather than a backdrop for the real action' (Mills and Comber 2013: 412) and includes studies that focus on the politics of places and place-conscious pedagogies across localised and global contexts. In our work in makerspaces in schools, we began to notice and attend to how both physical and virtual spaces and places shaped the digital storying that emerged.

Facet 3: Temporality

When considering how time inflects with the process of storying and making, try to think of moments when you are engrossed in a topic online and lose all sense of time and your consciousness of time alters as you move across hybrid texts, spaces, and platforms. Given the amount of exposure people have to screens, it stands to reason that time has significance for this type of screen-based technology. One study which explored engagement with technology during the pandemic revealed that time was experienced by participants in a range of ways: losing time in digital wormholes, new temporal rhythms due to increased curation of digital information, discrete time versus multiplicities of time (Rowsell 2024). Henri Bergson (1910) writes about durational time as time that exists outside of clock, linear, lock-step time. Durational time has always existed, and it is by no means only digital, but we would like to move into what makes postdigital time distinct and this is the qualitatively heterogeneous nature of it. What distinguishes postdigital time from lived or everyday time is how multifarious and heterogenous digital texts, practices, and levels of affect accessed can be as people read/write/watch/become across them. There is a quality to time across screens on the same or an evolving topic (starting on one topic and then in following a series of hyperlinks and allowing anticipatory software the ability to cluster our habits, desires and predilections).

Within his philosophical framing of time, Bergson (1910) describes qualities of time or 'feeling in time'. Bergson speaks of homogenous duration which is a pure consciousness, away from ego and we cannot measure it—we feel it in its entirety (e.g. not sensing time in a dream as we sleep). What we signal in this article is digital time, which is aligned with what Bergson (1910) describes as heterogenous time.

This quality of time happens when spaces and objects melt into each other. It is time that permeates across experiences from YouTube to Instagram to BBC news feeds which you cannot separate out as chunks of time, but rather as folding into each other; or, as Bergson says, '[b]y separating these moments from each other, by spreading out time in space, we have caused this feeling to lose its life and its colour' (Bergson 1910: 133). During the observations of digital storying in classrooms we observed children working over extended periods on new creations and teachers often commented on the focus and stamina of children as they retained their individual and collective focus on making. The children appeared to be in a 'flow' of making across physical and virtual spaces and teachers often shared reflections with the Maker{Futures} team on the ways that many children were working for much longer periods of time than they had observed in other sessions.

Facet 4: Practices

Practices considered *postdigital* are the actions and implied skills that take place across material and digital types of meaning making. What makes these practices unique and different is the increased merging and blurring of screens with physical environments to fulfil meaning making and social functions. There are newer communicative repertoires that have emerged since before 2000 that are linked to new technological innovations, the rise of AI, the presence of more platforms, and advances in haptic technologies (Jewitt and Price 2024). Nonetheless, new innovations do not usurp old ones, rather they amplify experiences of digital and non-digital working together. For instance, a child with a wearable VR headset can touch a virtual 3D object that appears in front of them through software. In other words, postdigital practices do not replace pre-digital practices in that digitally mediated touch, in this VR example, has not replaced physical senses ignited through touch (Jewitt and Price 2024). In fact, postdigital practices often produce actions and ways of thinking that augment and extend real-world connections. There are creative new possibilities that coalesce bodies, senses with haptics and converged technologies.

There are postdigital practices that take place during maker moments that vary based on storying that takes place (e.g., building a physical artifact with bulbs integrated into the design vs. making a TikTok video). Within schools there remain classic schooling practices like writing text genres (e.g., an essay), but there are ever-increasing newer postdigital practices like uploading a design onto digital portfolio platforms (such as SeeSaw). What makes postdigital practices distinct are the ways that older practices (building a cardboard artifact) combine with newer constellations of digital practices like using Octostudio to bring a physical object to life.

Many postdigital practices are situated within an extended social-cultural tradition of making and a theorist particularly adept at articulating this is Anna Keune. Anna Keune's (2022) research on 'mathematical doing' applies traditional craft skills like crocheting with yarn and needles combined with emerging technologies embedding microchips in fibre crafts to teach children about mathematical principles like proportional patterning. She identifies how fibre crafts are contexts for high-quality lifelong STEM learning because physical materials drive digital skills. Drawing out

the socio-historical links between fibre crafts and coding, Keune (2022) illustrates that low and high technologies used by children and young people are nested within an expansive sense of composition. Material design work advances contemporary digital learning because it spans analogue and digital, low and high tech, and what we have observed as makerspace researchers are the ways that children and young people enact this type of learning event quite naturally and with notable resilience. Indeed, these practices have the hallmarks of what Merchant (2023) signals as a new ethos of composition:

> These changes constitute a shift in the social and material relations that writing participates in and acts upon. On a macro-level this has involved shifts in the topology of communication – changing relations between writing and speech, changing relations between writing and image, innovations in pictographic representation and the development of writing with, to and by machines. (Merchant 2023: 158-159)

Recognising movements across embodied, physical spaces with haptic, virtual ones is consequential because postdigitality offers a language of description, framework and models for thinking and learning between humans and machines and human touch vs. screen touch (Jewitt and Price 2024). In the next section, we foreground the methodological approach we adopted to understand the significance of 'maker moments' (Murai et al. 2019) in classroom contexts.

Methodology: Noticing Maker Moments

How do we understand the significance of children's making practices? What meanings and possibilities emerge and how do we attribute value to these? In this paper, we build on the work of Murai et al. (2019) and extend this to present a postdigital conceptualisation of 'maker moments' as a methodological and pedagogical practice of recording and reflecting on moments of making. In doing so, we draw on a range of field note data to explore and highlight the value and importance of 'seeing what becomes' as children and adults tinker with materials, experiment with possibilities, and engage in meaning-making. From a pedagogical perspective, maker moments present an opportunity to make connections with children's identities and lived experiences (Cannon et al. 2022). They involve us in moment-to-moment intra-actions (Barad 2007) as human and non-human entities (such as materials and spaces) combine and influence emergent outcomes. Posthumanism and sociomateriality (Barad 2007) did not initially inform our theorising and foregrounding of 'maker moments' in the Maker{School} research, rather the notion of intra-action connects with our analysis of the data and our overall message in this article. Intra-action as a notion helps us to show that postdigital storying actively moves across and shapes spaces, times, materials, and practices.

So how do we attune ourselves to, and notice, the many intra-actions within a storying event? Noticing is about being open and ready to be affected by the moment, as a researcher. Noticing involves listening in all of its multiplicity (Davies 2014). Noticing within research demands not being bound by what we already know, but

being open to what unfolds from the maker. Noticing is also being led by intuition, playfulness and curiosity rather than seeking out 'evidence' of particular pre-prescribed outcomes. However this can be difficult and, Goouch highlights that: 'ascribing value to and deconstructing teachers' intuitive playfulness, in order to make the pedagogy explicit and to give it status, is always a challenge as those involved often fail to see value in that which is intuitive rather than predetermined, and of course such practice does not sit neatly in audits or simple measures of accountability' (Goouch 2008: 95). Tsing (2015) extends the notion further in using the term 'act with noticing' to move beyond physically working with people and matter to explore enmeshed connections across things/matter and people.

During our Maker{Futures} research project then, we took a deliberate 'act of noticing' stance on makerspace pedagogy across five schools. Given that the research[3] evaluates the effectiveness of maker approaches to learning in primary and a special secondary school, noticing became an essential research practice. Patterns started to form about making and how it fosters resilience and making to bring into the fold learners who struggle with more traditional forms of learning like reading silently or completing written compositions. Making moved learners who are often marginalised into the centre of classes. What is more, the actual properties of making involved physical materials like cardboard and scissors as well as alligator clips and Micro:bits. We noticed frustration during making for sure, but we also noticed sparks and epiphanies (Sakr et al. 2023).

The act of noticing occurs moment-to-moment and also evolves over time. School pedagogical practices still tend to focus on evaluating products rather than valuing processes involved in making (Colvert 2019, 2022). At first, we had an evaluator lens on how teachers and students engaged with and enacted in makerspace activities during class time. Some teachers took a measured approach, adding in maker-oriented components into a few lessons every week. Other teachers took a middle-ground and applied making in content areas like English, designing sessions which were almost entirely informed by making. Finally, there is one Early Years context that was almost entirely premised on makerspace pedagogies. By November/December of the year-long research, we took a closer gaze at the nature of making as in: materials chosen; classroom space set-up; pedagogical framings of making; teacher roles in making; and perhaps most of all what motivated students and degrees of resilience as they worked on design. There are ethical dimensions to data collection here and we chose not to take photos of anyone, to preserve anonymity, but instead just children and young people's designs. To get a bird's eye view of learner-driven designs, we observed the beginning, middle and end of each lesson and took photographs of final designs as well as the making in progress. A key dimension of our fieldwork was sitting alongside makers and co-designing or helping them and talking through the emergent storying of their designs, and we took fieldnotes during this process. Consent was obtained from all participants, including

[3] Funding: University of Sheffield Knowledge Exchange Grant on Maker{Futures} Innovations and Implementation in Primary and Special Schools. 1 October 2023–1 June 2024.

teachers, parents and children and the research underwent a full ethical review at the University of Sheffield before we undertook any data collection.

Data Analysis: Maker Moments

We will now examine how attending to and reflecting on moments of making can support educators to understand the multi-faceted and shifting nature of postdigital literacy practices (Bhatt 2023) (and the ways that a focus on making opens new possibilities for learners (particularly those learners on the margins). During the research project, we asked all teachers to select maker moments that were 'significant' to them and researchers also collated and recounted such moments, making observations during sessions and keeping reflective logs. In our analysis we draw on the concept of crystallisation (Richardson 2000; Richardson and St. Pierre 2005). Richardson (2000) in her essay 'Writing as a Method of Inquiry' proposed that in qualitative research scholars interweave literary, artistic, and scientific genres that break down boundaries between fields and composing across these fields. As Richardson maintains: 'in these productions, the scholar might have different 'takes' on the same topic, what I think of as a postmodernist deconstruction of triangulation. … In postmodernist mixed-genre texts, *we do not triangulate, we crystallize.*' (Richardson 2000: 934) (emphasis added). During the project, we gathered maker moments that we observed and reflected on these in discussion with each other and the teachers with whom we were working. We held each moment up to the light, as if it were a crystal, and viewed it from different angles, looking at the different facets (spaces, time, materials and practices) and how these refracted and reflected the digital. We also witnessed the steady crystallisation of matter, mixed genres and interactivity as students made artifacts/designs.

The three maker moments presented here are representative of the broader data set in that they highlight different types of making opportunities that emerged over the course of the research project and illustrate the creativity, dynamism, layering, and dimensionality that happens across schooling contexts. The data presented includes transcripts from discussions with teachers, observations, and field notes (including photographs) as well as texts created by teachers and children (such as film footage). In the three 'maker moments' (Murai et al. 2019) that follow we examine the fieldwork to draw out postdigital storying and practices enacted and experienced from the perspective of teachers.

Maker Moment 1

The first event took place in a year 2 classroom in the South of England and was recorded by a child and shared with the teacher, following a CPD session which had been delivered by the Maker{Futures} team in January 2024 which had included training on different ways to join cardboard. A researcher (Angela)

visited the school in May 2024 to gather teachers' reflections of the 'moments of making' they had recorded in their classrooms. One of the teachers had selected a few examples of making which had been recorded on their digital portfolio platform (SeeSaw). The example discussed here was not observed by the teacher, or by the researcher, as it took place during 'choosing time' when children can decide what they want to do. The teacher explained:

> In Year 2 I don't take the photos. They take [them] themselves so it will be things they have captured themselves ... So, she made this and obviously I didn't know what she was doing. The she filmed it to show what she had made ... We were reading about the Wild Things but then she went off to make this out of cardboard but there is a little surprise at the end!

The teacher then accessed the child's digital portfolio where the film had been uploaded and played it to the researcher. What follows below are some screenshots from the film with accompanying narration by the child (Fig. 1).

After the teacher and researcher had watched this together, the teacher explained why this seemed significant and why she had selected this as an example of a 'maker moment' to share. She explained:

> So obviously she's worked on that for a sustained period of time and having her own creative ideas ... and having that space and that time to do that and for all the materials to just be available to her … and you know the little baby inside and you know even the way she has recorded her video she's got ownership of it the way that she has edited it. We don't have any books, only writing book, for everything else we use an iPad for them to record their work ... There is definitely innovation with having the baby inside and [it's] autonomous because she's done it completely on her own and she's figured out ways to join the materials together with whatever materials she's wanted that she's gathered herself ... She's making connections with her learning and the story ... Our timetable is very supportive of that where they can have that uninterrupted time when they can choose their own learning.

This is an interesting example of a 'maker moment' as the making of the monster and the making of the film occurred out of sight of the teacher. The filming and sharing of this work were done independently by the child with the intention of showcasing the model she had made, whilst also providing an exciting narrative experience for the viewers (teachers and parents).

If we return to the metaphor of the crystal, the many facets of postdigital storying are represented in the teacher's reflections and responses to this film. For example, in relation to materiality, the teacher is struck by the way the child had worked with the cardboard and paper to find ways of attaching them and by the way the materials were selected to meet the design purposes of the child. Also, the materiality of the iPad itself, used to record the film is important, as it is portable and allows for editing to occur alongside documenting the narrative. In relation to the spatial facets, the physical spaces in which the making took place

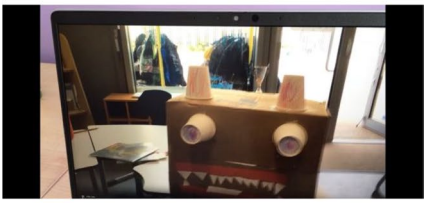
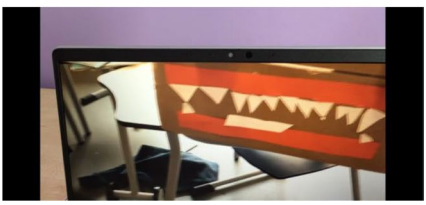
	Don't scream or he will hear you….
	This is a monster
	He has one set of googly eyes
	This is his brain and..
	Sharp TEETH

Fig. 1 Filming the baby monster

were also significant; the teacher notes that the child was able to access materials independently when creating the monster and, in the filming, space was used in playful ways as the baby monster was deliberately hidden inside the box and hidden from the view of the camera until the very end of the film. Time was also reflected upon by the teacher, as she noted the sustained length of time that would have been needed for the child to create the monster and film it and the timetable allowed for this self-directed exploration and play to occur. In relation to the

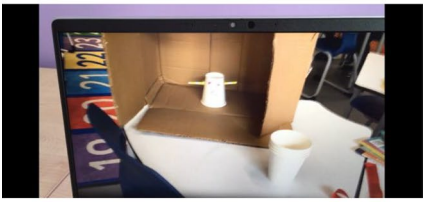
	And at the back… inside he has….
	A BABY MONSTER! Oh not this will…
	(High voice) I'm not… I'm not going to do anything I'm just (inaudible)
	So baby monster is stuck inside
	like a little house so…tell me if you like it.

Fig. 1 (continued)

practices reflected in this example of storying, the teacher noted the way in which the child was taking inspiration from a book they had been reading in class and recognised this as an act of literacy. However, the child too was drawing on the wider practices in the classroom of documenting achievements and things they were proud of using their individual digital portfolio—highlighted in the phrase 'Let me know if you like it'.

Maker Moment 2

Over the course of the 2023/2004 academic year, another researcher (Emma) worked with teachers from a local primary school in the North of England. The aim was to explore how making might be relevant in their teaching practice. The following assemblage of maker moments is drawn from a session where she joined the teachers' year two class (6–7-year-olds) for the morning. The session had been planned by the teacher who asked the children to consider 'What makes a perfect planet?' They were then given a range of materials and tools (including iPads) to create their perfect planet. Figure 2 shows how the teacher arranged the space to create places where children could spend time choosing materials, returning to the stations whenever they needed to and made use of a spare classroom to make possible the production of large-scale artefacts.

The researcher was able to spend some time around the materials and tools whilst the children were selecting items to use. She recorded the sound of the children as they deliberated about what to choose, what materials they liked and how this shaped what they were going to make. She noticed that whilst some children were selecting materials because they fulfilled the requirements of their

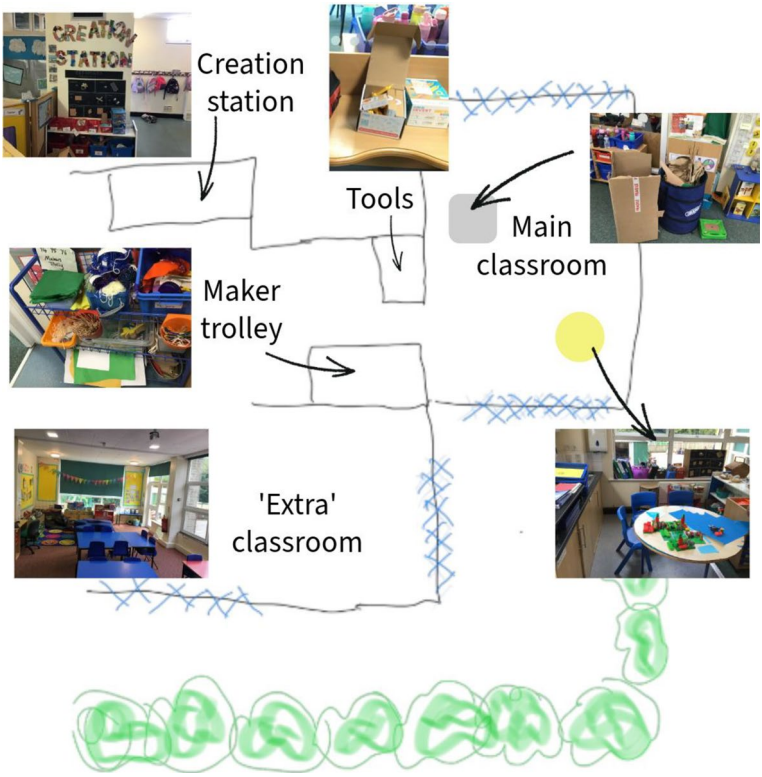


Fig. 2 Spaces for storying

idea: 'I need three of those because I'm going to make chocolate straws'. Others were more speculative: 'Oooh we could use this…What is this?'.

This relationship between the materials, the design, and the artefacts became more enmeshed throughout the process as children were able to revisit the materials and started to use materials beyond those provided by the teacher including going outside. The teacher later reflected on this with the researcher, explaining that: 'We wanted the children to have complete free reign – so we had the maker trolley and the makerspaces … We had two spaces that they could work in and they could use any resources and they could ask for anything they couldn't see' (Class teacher). Central to this process of making was the way in which the materials were distributed around the classroom but accessible.

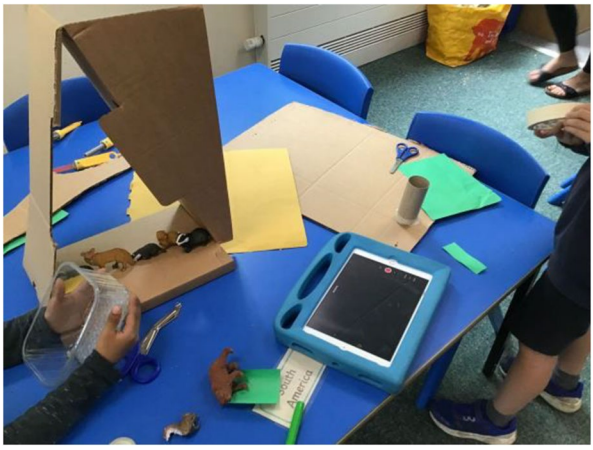
The iPads were located within the classroom by the cardboard (Fig. 3) and also next to the trolley of materials (Fig. 4). The researcher had spoken to the teacher prior to the session about including the iPads next to the other resources in this way and she was keen to see how the children might use them without a specific task or guidance. One child was intrigued by the appearance of the iPads alongside the other materials area but unsure how he should use them. He turned to the teacher for guidance, 'What are the iPads for? What are the iPads for? Miss, what are the iPads for?' Eventually the child began to work with his group (see Figs. 5 and 6) as they selected a range of non-digital materials.

For a long while, the iPad just sat on the table next to but not integrated into the making. After about an hour, one of the children in the group asked the teacher about the iPad again and whether they could play games on it. After being encouraged to integrate it into the project, the child decided to use the app Octostudio, which supports the recording and editing of sounds, the creation of animations with code as well as photos and digital images. The class had already used the Octostudio app in a previous session and so he was familiar with it. The photographs he had previously taken of the making were now incorporated into the software as food for a 'dragon sprite' who was animated to appear as if it was eating paper. The researcher stood beside him as he used the software:

Fig. 3 Digital technology (iPads) placed next to non-digital materials

Fig. 4 Digital and non-digital materials and tools

Fig. 5 The triangular cardboard



Child: 'It's changing colour!'
Researcher: What is the dragon doing?
Child: 'It's changing colour! He's trying to eat the paper!'
Researcher: 'Have you done that?'
Child: 'Yes, I made the dragon change colour!'

Another member of the group then retrieved an iPad and began experimenting with sounds to add to the creation (see Figs. 7 and 8).

A few days later, the researcher was able to spend some time with the class teacher, returning to the photographs, videos, and sound recordings she had made. In this context, the teacher and researcher moved beyond the digital capturing of 'maker moments' towards a way of reflecting on educational events. During the discussions many facets of postdigital storying were evident and emerged as being significant. For example, initially the teacher (whilst looking at Figs. 5 and 6) began to

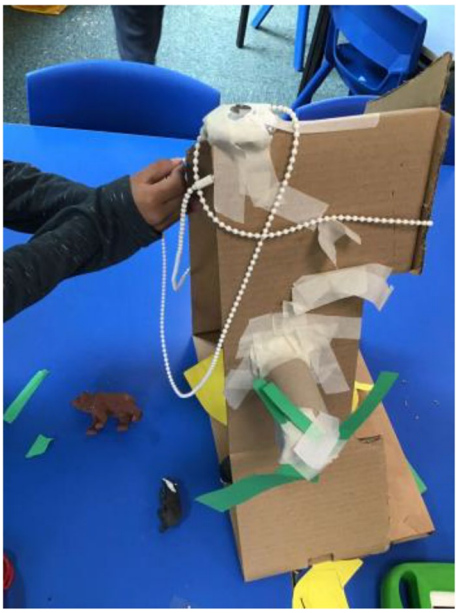


Fig. 6 Draping beads from a blind

Fig. 7 Adding sound to their forest using Octostudio

reflect on the materiality of the making: 'They chose this piece of triangular cardboard, they grabbed it … they obviously liked it. They started off and it was a forest and some animals. I supposed they were quite influenced by the material…Then the beads were from a blind and they asked if they could use them.' In this, she noted the way children were drawn to particular materials and that the materials also seemed to influence and shape the making process. She also reflected on the inclusion of the digital:

> The iPad is there just on video capture - that's interesting … I wonder if that's what they went to first because that's what they're most familiar with using the camera and video, they use parents' phones so it would be really really accessible … Oh yes I remember (one child) came to ask me: what could the iPad

Fig. 8 A round table on which children constructed a world

be used for? And I said 'well anything really, what are you thinking?' and he asked if he could play a game. And I said 'well I'd like you to use it for what you are doing with the rest of the children' and so I think that's where he went on to the Octostudio.

This highlights some of the tensions inherent within how teachers and children are navigating postdigitality in schools. The 'not knowing' what to do with the iPad indicates that this digital tool is not yet a part of the school repertoire in the way that perhaps it is at home. The class teacher acknowledged that iPads are generally used by children to either document their work or to complete specific tasks. It is interesting that when the question about what to do with the iPad was met with an invitation to choose, the child suggested a game. The iPad for this child seemed not to be a tool—one to be used alongside the other ordinary materials but had a different 'special' purpose. This is perhaps because the iPads were often used for specific purposes in learning contexts and were not generally offered as another open resource or option for making.

Figure 8 shows a perfect planet artefact made by two children from another group. Here reflecting on the photograph prompted a reconfiguration of how the teacher had originally responded to this maker moment: She said: 'He often chooses to work there, it's away from the rest of the class … so he's very comfortable in that space … he gravitated towards this table.' In this she appeared to draw on a social-constructivist framing to make sense of the learning, reflecting on the child's interests and needs. However, after a few seconds of looking at the picture, the teacher commented 'I think they've made quite a literal representation of a perfect planet—I don't know if that's why they chose the table—maybe it was—it's just made me think…' Here, the teacher is able to use the temporal affordance of the digital to reflect on the materiality of the 'round world' table as an agent within the making process. Spatially and materially, the table is like a world.

Taking the facets of our crystal metaphor to understand digital storying, we see that in relation to materiality the non-digital materials and spaces were prioritised

early on by the children but as the ideas evolved the digitality became part of the creation. Firstly, through the animation of a paper eating dragon on Octostudio, followed by the inclusion of digital sounds. Children were drawn to particular spaces and could move within these spaces. Acknowledging and noticing this was important for understanding both how the children engaged in the process of making and the artefact produced. Spatiality was also interesting in that the proximity of digital technologies (the iPad on the table) did not necessarily lead to its integration of digital into the making in the early stages of storying. The temporality of the storying was remarkable in two ways both in relation to the impact of extended making time on the ways the ideas evolved over the day and the use of digital artefacts to 'freeze a moment' to enable the researchers to consider it and think otherwise. In relation to considering making practices we reflected on the ways that schooled uses of the digital inflect with this act of storying. Reflecting on maker moments with the teacher generated new knowledge about the educational encounter.

Maker Moment 3

Let's take an example from Maker{Futures} research over the 2023/2024 academic year. On 26 June, two researchers (Jennifer and Alison) attended a maker day at a special school in the Northwest of England. Michael and Candace (pseudonyms for participant teachers) are part of the Maker{Futures} knowledge exchange evaluation project that we have referred to throughout this article. Michael is a Subject Lead and he believes strongly in active learning and in makerspace approaches to learning. Michael is an advocate of makerspace moments as ideal forms of active learning that ignite sparks and interest from students (Sakr et al. 2023). Michael creates an ethos of making in the school and there have been noted advances in student interest, investment and resilience as a result of this focus.

During the day, the researchers (Jennifer and Alison) spent most of their time in two classrooms. One class is a year 8 class (Candace's class), and the other is a year 9 class (Michael's class). Both classes chose the theme of the upcoming 2024 Paris Olympics as their focus and they followed the same process: (1) talk about Olympics sports; (2) choose a sport; (3) choose materials; (4) make, design and construct; (5) decorate; (6) add in digital features—mostly micro:bits; (6) functionality testing; (7) tweaks and design iterations; and (8) present final design. This work happened over 2 weeks. Bear in mind that students had a variety of disabilities which played a role in the types of making practices that they could engage in.

Figure 9 shows a basketball court made by Liam[4] (with help from his teacher Candace) and Jennifer sat with them as they tested its feasibility and fixed the design. Basically, the programmed micro:chip connected to the cardboard hoop was not accurately keeping score, so Candace solved it by adding in tin foil flaps that triggered the micro:chip when the basketball went through the hoop. Figure 10 was made by Aliya (pseudonym for another participant student), who built a Pony Chop because of her love for *My Little Pony*. In brief, the pony would chop fruit for

[4] Liam and Aliya are pseudonyms for two participant makers.

Fig. 9 Olympic basketball court

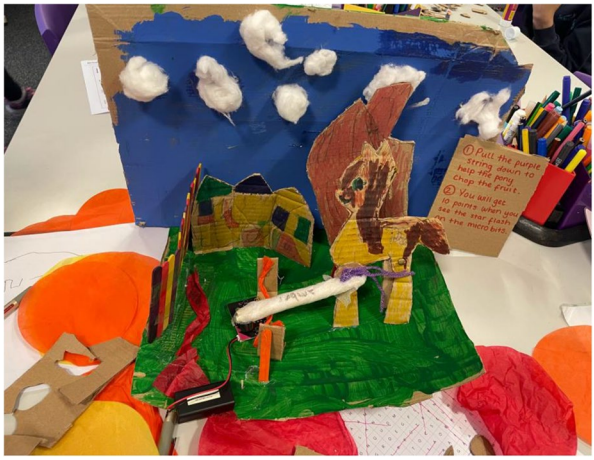


Fig. 10 Olympic pony chop sport

points (which was tougher than it sounds). Aliya was detailed about the nature of the design that featured a pony whose hoof has a magnet on it that drops on a chopping board (micro:bit) to chop fruit. The micro:bit shows a flashing star each time the fruit is chopped. The magnet, the chopping arm and the micro:bit are essential to the design—without them you would not have a game.

Drawing in the crystal metaphor, the basketball court and pony chop designs illustrate all four facets. In relation to a temporal facet, the making sessions took place over 2 weeks with the build-up to the maker day on 26 June. The two featured classrooms chose the Olympics to frame student storying. Both teachers devoted the first week to investigate Olympic sports and their spatial, embodied, and material properties. To do this, groups watched YouTube videos of previous Olympic sports events; groups shared photos of athletes; and, there were group discussions comparing and contrasting different Olympic sports. Students were then given time to plan out their designs. The second week was devoted to completing their designs. So, in

this way, time was sequential and designs evolved over days. Based on our experiences in the special school over the academic year, teachers usually planned lessons across longer timescales (Lemke 2000) so that ideas built up over time and so that students did not feel overwhelmed by a task—the idea could grow and morph into whatever took form. At the end of the 26 June maker day, Michael admitted that he had deliberately created blocks of time so that students could move inside of maker moments: 'So because they had the freedom of going off timetable a bit, throughout their English lessons, they, we weren't under, you know, scrutiny to be delivering specific things in English. They kind of had a bit more space for trial and error with making' (Michael).

In relation to space, the planning, discussions, making, and crystalised maker moments all happened within classroom spaces. Each class had desks gathered into groups of four students with the teacher's desk somewhere near the front. Every class had a sink and small work area. In this way, the space had a standard schooling feel to it. Both classrooms felt compact with 3–4 adults milling about and 10–15 young people moving around, and there was a sense of flow and energy and at the same time chaos in both spaces. It is important to note that making happened because of and not despite the slightly chaotic and busy feel to the room. Students felt comfortable moving around to seek out help, grab cardboard or a glue gun, or share an idea or check out someone's design. There was a running joke across the two classrooms about stealing glue guns and then having to bring them back and forth which created a liminal space between the two classroom environments. Students worked independently, however, often sought advice or technical help when they needed it. There was a therefore permeability to the pedagogical spaces—a sense of flowing in and out with an overarching commitment to making across both classrooms' settings.

The two classes had a strong material presence. Cardboard, micro:bits, lost glue guns; alligator clips; and LED lights were talked about, accessed, and shared all of the time. Most conversations evolved around materials as agentive forces—as essential parts of thinking about and through making. It was Emma who noticed that making changed when physical materials met digital materials. That is, constructing a basketball court or equestrian/pony game went from a cardboard replica with individual artistic flair to an interactive, live object when digital material was incorporated into the design. We both observed a conversation between Candace and Liam. Candace suggested that in order for the basketball hoop to sync with the attached micro:bit, they had to add a tinfoil flap (seen in Fig. 9) which the basketball grazed to trigger the programmed micro:bit to change the score. The entire discussion revolved around trial and error and remaking until it worked. In this instance, physical materials ignited digital materials. With the pony chop, most of our discussion dealt with ways of making the horse's one hoof trigger the micro:chip. The pony chop game was more digital because its whole logic depended on the hoof chopping fruit. With the basketball hoop, the micro:chip kept score, which could well have been done by clapping a hand or counting on your fingers or yelling out the score.

Practices were different from their standard writing tasks because maker moments display a different constellation of practices. Problem-solving featured prominently as did motor skills like wrapping a wire around a wooden stick. Adult–child teaching was far more present with teachers and researchers sitting alongside student makers

more as peers than adult teaching child. Jennifer remembers Aliya speaking with her and Candace about what the pony chop design had to look like and the importance of a magnet on the hoof and the language necessary for directions on the cardboard sign. Similarly, Candace was especially animated as she solved the basketball design (i.e. the tin foil flap) and worked with the maker to make the design function. As we left the school on 26 June, Michael said:

> The more we do it, the better they get at it. At the beginning, you know, when things go wrong, they found that quite hard to cope with. But because we've, we are sort of trying to build loads of stuff and we're doing it more, the more you do it, the more they get used to the idea that it's, it might not turn out. And I think it's also about the approach we've taken. I think if you use an image of something that you are trying to achieve, it's hard, it's much easier to feel that kind of yeah. Feel let down, disappointed, angry that your product doesn't look like, like the one, the one on the screen. Yeah. So I think it's about the, the, the way we deliver it and just the, that they're getting more used to making a lot and so they're getting more used to kind of failure or not just failure, but things not working in the way that they anticipated, but also not trying to achieve a very sort of specific end product helps. (Michael)

Emma talks a lot about maker moments fostering resilience and it really hit home on this occasion that making not only crystallises design thinking, but also, making crystallises a sense of purposeful criticality.

Discussion: Postdigital Storying as a Spectrum

So, what does this approach to 'noticing' maker moments enable us to do? What is 'seen' in the episodes described here? What is unseen? What emerges? When you look at a crystal from varied angles, light filters through in multiple ways. Similarly, postdigital storying as represented in this article allow for different light refractions into the crystal of postdigital storying. Maker moments (which are numerous and could take place over several days) are instances within the process of postdigital storying where children create artifacts and events from an original idea (as with the film of a baby monster trapped in a box as seen in maker moment 1) and then bring in digital effects and animations with materials (as in maker moment 2) or integrate electronic components into artefacts (as in maker moment 3). There is a negotiation between technologies, tools, materials and software that takes place during maker moments that typifies postdigital communication. To illustrate the complexity and dimensionality at play when making, we explored the intersection of four key facets: materiality, space, time, and practices. This way of documenting educational events to better understand postdigital storying moved us beyond the digital 'capturing maker moments' to conversations between researchers and teachers about how the many facets of the storying (material, spatial, temporal and practices) come together to form 'ontological entanglements' (Barad 2007: 332). In this we shifted our collective focus

from the what and how of making to a more Deleuzian consideration of what is interesting, remarkable or important (May 2003: 140).

We have used the metaphor of the crystal to explore the various facets of postdigital storying, focusing on spaces, temporality, materiality, and practices in maker moments. We now extend this metaphor further by considering how the spectrum of the digital (acting as light in this metaphor) is refracted by or absorbed by the process of making and by each facet (see Fig. 11). In doing so, we shed light on the extent to which instances of multifaceted postdigital storying moments are suffused with the digital. There are a range of configurations across all three maker moments that we might consider here ranging from opaque storying events (which require very little of digital) to transparent storying events (that let in and integrate the digital into the design through every facet).

What filters through a crystal are different forms of light (digital elements) that invite different kinds of experiencing. When holding a maker moment up and rotating it to view different angles people witness, explore, experience, analyse, and question a mosaic of refractions of light (digital) through the prisms and fractures in the crystal. There are maker moments that are opaque where the light of the digital is not refracted or reflected (if the digital is not needed wanted or accessible). There are also maker moments that are highly reflective (that showcase the digital without it's light reaching its core), and there are those moments which are transparent where the digital suffuses the crystal through and across each of its facets (creating iridescent configuration of light/digital). One 'type' or composition of crystal is not any better or worse than another, we just use the metaphor here to try and highlight how postdigital storying intra-acts with the light of the digital across different contexts.

Circling back to maker moment 3 with the metaphor of light through a crystal, moving into the designing of the hoop with the tin foil flap that triggers the micro:chip when the ball passes through, there is an opacity to material-digital

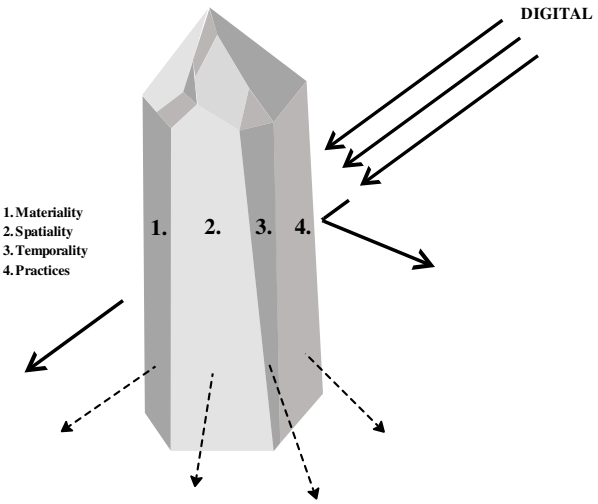


Fig. 11 A diagram to illustrate how a multifaceted moment of making reflects, refracts or absorbs the light of the digital

relations. By this we mean that, metaphorically speaking, the digital is not refracted or reflected, the digital functions yes, but it does not suffuse and inform the design as much as the magnet does as it hits the metal circle connected to the micro:chip. The pony chop design is more reflective and transparent as a crystal because the design showcases and indeed relies on the digital to function. As we say, one design is no better than the other, but the crystal metaphor helps us to capture the amplification and dulling of digitality or materiality.

Across all three moments of making the focus was on the child as the one with 'agency' to make and express ideas. However, throughout the teacher and researchers' reflections was an awareness of the 'draw' and 'appeal' of particular materials and the possibilities that emerged as children manipulated the materials they had to hand. Indeed this materiality was central to all three moments of making described here, with the teacher noticing that 'they were quite influenced by the material'. The material too can be seen to have a form of agency then too, in the way it bends (or not) to the will of the child or suggests a new way of working. The maker moments are described here from a human-centred perspective, but there are other perspectives too that might be usefully explored. For example, others have tried to tackle this though 'stacking stories' (Burnett and Merchant 2019) to capture and convey the role and agency of non-human actors.

Over recent years educational systems in the UK (and globally) have prioritised measurable outcomes rather than the process of learning (Colvert 2019). This paper demonstrates the value of noticing and reflecting on moments of 'storying' 'as a research approach which allows insights into children's meaning making'. Nevertheless, challenges remain in relation to the way we understand the learning taking place during postdigital storying. Murai et al. (2019) have suggested that 'due to … hands-on, collaborative aspects, it is challenging for teachers to capture in-the-moment evidence during maker-based learning') and that 'process-focused evidence collection tools are needed to make the internal state of a learner (e.g. ideas, questions, struggles, feelings, or inspirations) visible'). Although we encouraged teachers to record making processes, children and teachers tended to record reflections at the end of the process (as they were busy making at other times) and the software used to communicate learning with home was also primarily focused on the sharing of successes (rather than the messy process of trial and error and experimentation). However, researchers visiting classrooms were well placed to capture maker moments during the process of storying and were then able to reflect on these in discussion with teachers. In the next stage of research, we will continue to develop processes so that the children and teachers can capture moments of making at different stages. In doing so we have moved beyond the digital capturing of 'maker moments' towards using these to support reflections on multi-faceted processes. Our conversations with teachers, using films, photographs and observations as prompts enabled us to collectively explore 'ontological entanglements' (Barad 2007: 332). This then produces a shift from the what and how of making to more of a Deleuzian consideration of what is interesting, remarkable or important (May 2003: 140).

Concluding Thoughts

The three maker moments we present embody postdigital practices well because they exhibit the hallmarks of postdigitality such as: movements across material-digital, physical-virtual, clock time vs. sensed time/durational time, and fluidity across spaces. These practices are as much technical as they are socio-cultural, and they are not one-size-fits-all for all people but vary tremendously based on the person, place, and materials. For instance, the first maker moment describes a literacy event (Barton 1994; Barton and Hamilton 1998) when a child builds a story about a baby monster that she constructs out of cardboard and paper cups and a short film and then shares via SeeSaw. Such constellations of practices include choosing materials, cutting, glueing, constructing, then animating the object, then weaving together a storyline. It is as informed by the agency of the student, by material choices, by ways of filming the baby monster getting stuck inside of a cardboard house. However, this storying could be understood as an example of 'postdigital literacy' (Bhatt 2023) because of the the layering of digital and material texts and asynchronous and synchronous mobilities. These practices carry material-digital dimensions, they have a spectrum of physical and virtual spaces along with degrees of materiality and physicality. Postdigital storying involves actively melding material and digital entities, navigating real and imagined spaces; feeling in time; managing digital-material modes and resources; and engaging in arts and tech practices. We suggest that postdigital storying, as an act of meaning-making, is characterised by a range of intersecting factors and aspects that can be conceptualised as facets of a crystal (spatial, temporal, material and social) and that this metaphor enables us to envisage how each of the facets affects what we see and what emerges moment to moment as the light (the digital) is refracted. We argue that without ways of embedding postdigital practices into current curricula, as educators and policymakers, we are left without ways of accessing students' capacities and scale of competence taking place richly across contexts. Digital practices within school curricula tend to get flattened if viewed as technical or operational and we can then miss the dynamism and iridescence of making that actually takes place in makerspaces. This article has held three moments of making up to the light and we hope it moves closer to the kinds of curricular work children and young people that sustain their interests and support a real, lived sense of being digital now.

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Data Availability The data set which underpins this article is not publicly available as it consists of qualitative data that might potentially put confidentiality at risk if shared beyond the research team. All extracts from data are pseudonymised in publications.

Declarations

Ethical Approval This research underwent full ethical review at the University of Sheffield.

Conflict of Interest The authors declare no competing interests.

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