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Digitally amplified practices: Beyond binaries and towards a profile of multiple digital coadjuvants

Marilyn Fleer
Faculty of Education, Monash University, Melbourne, Australia

Abstract

To examine the agentic conditions afforded through the use of digital tools in play-based settings, the Vygotskian (1997a;b) concept of imitation was used to study the pedagogical practices of two teachers over two years (Group 1: 3-5.8yrs, mean 4.5yrs; Group 2: 4.7-6.7, mean 4.5). Rather than a static view of digital technology, where screen time acts as a proxy for understanding the child's experience, this study found a complex profile of practices where digital tool use could not be separated from the existing preschool program. It is argued that these digitally amplified practices, named as coadjuvants, support children's development.

Keywords: digital device; apps; transformative; cultural-historical; early childhood

Introduction

Much of the longstanding literature into the nature of digital screen time in early childhood settings has inadvertently presented a binary between play that features digital devices and play that occurs without these devices. These conceptions have been named variously as traditional play vs contemporary play, concrete real world play as opposed to iWorld play, and spontaneous play vs digitally programmed play or gaming (Edwards, 2013; Edwards, Henderston, Gronn, Scott, & Mirkhil, 2016; Marsh, Plowman, Yamada-Rice, Bishop, & Scott, 2016; Stephen & Plowman, 2014; Verenikina, Kervin, Rivera, & Lidbetter, 2016). Although most try to work against these traditional conceptualisations, it is difficult to write

about digital practices without referencing the technologies.

Nevertheless, binaries silo practices and narrow the research focus to one binary node or the other. As will be shown in the study reported in this paper, this boundary framing of digital devices does not reflect the nature of digital practices in preschool settings which goes well beyond the digital tool itself (e.g., Danby, Davidon, Ekberg, Breathnach, & Thorpe, 2016; Kumpulainen, Mikkola, & Jaatinen, 2014). Even at a common sense interpretation, a binary makes it difficult to explain how a child can be both pretending and using a digital tool in play (Björk-Willén & Aronsson, 2014; Mirtes, 2014). Consequently, a binary limits the possibility for understanding holistically how practices change and what this affords for children's development when digital devices are introduced into preschool settings.

Further, with these binary conceptions has come a focus on the threats and concerns associated with the introduction of digital devices in relation to consumerist engagement and problems associated with increasing amounts of screen time of young children (Walker, Hatzigianni, & Danby, 2018). It is argued that this traditional framing and alarmist orientation for the introduction of digital devices in early childhood settings does not speak to the transformative and agentic developmental conditions (Stetsenko, 2017) that are created for very young children when given access to digital tools (Danby, Fleer, Davidson, & Hatzigianni, 2018). As will be shown in the study reported in this paper, the digital tools open up new possibilities for children because they are no longer limited by their biology – they can type letters to easily express their thoughts, they can zoom in on the small detail they are interested in exploring, they can access text through activating speech icons even though they cannot yet read, they can use digital microscopes, something that secondary students in the past struggled to use in the field, and so on. It is argued that digital tools give new possibilities to very young children and therefore create new developmental conditions.

With this agentic perspective, the focus of this paper is twofold. It studies from a cultural-historical perspective (Vygotsky, 1966) the practice traditions in which digital technologies are being introduced, whilst at the same time theorising the introduction of digital technologies not as a static binary, but rather as a dynamic relation between societal values, institutional practices and a child's motive orientation (Hedegaard, 2014). With this backdrop, the paper discusses the new practices and how they create agentic developmental conditions as two teachers over two years introduce digital devices into their teaching program. Practices are presented as profiles of multiple digital practices for supporting children's development.

To achieve the twin goals of this paper, a theoretical discussion is first presented, followed by the study design, the findings, and then concluding with a holistic model of dynamic characteristics named as digital coadjuvant, where more discussion of the current literature is given to frame the significance of the findings.

Theoretical foundation for studying digital interactions in preschool settings

Child development is central to any study of young children entering into the practice tradition of a preschool. With the introduction of digital tools (Marsh et al., 2016) and the emergence of digital pedagogical practices into preschool settings (Arnott, 2017), it has become increasingly important to understand how these digital devices create new cultural conditions for children's development. Consequently, in this study, child development has been theorised from a cultural-historical perspective because it allows digital practices to be conceptualised as part of the cultural development of the child (Vygotsky, 1998).

The concept of the cultural development of the child was first introduced by Vygotsky (1998) in opposition to a behaviourist view of development. Vygotsky (1997a) conceptualised development not just as a biological process (stimulus-response mechanism),

but rather discussed development as a cultural practice defined by developmental periodisation, where he foregrounded ‘the cultural age of the child’. He said that,

> …cultural development of the child represents a special type of development, in other words, the process of the child's growing into a -culture cannot be equated, on the one hand, with the process of organic maturation and on the other, it cannot be reduced to a simple mechanical assimilation of certain external habits. If we take the point of view that cultural development, like all other development, is subject to its own patterns, its own stages, then the problem of cultural age of the child seems completely natural (p. 231).

A cultural-historical view of child development not only discusses development in terms of how the environment (social and material, including digital) acts as a source of development (Vygotsky, 1994), but through conceptualising the child as always in a process of cultural development, it becomes possible to better understand how changes in societal, institutional and personal situations (see Hedegaard, 2012), such as the introduction of digital tools, can and do create new developmental conditions for children. Although Vygotsky’s conception of development was formulated before digital devices became mainstream in society, his dialectical view of development offers a holistic conception, and therefore is an alternative to the binary default that appears in the literature. Three key conceptualisations of cultural development that are foundational to the present study follow.

First, in studying human development, Vygotsky differentiated two lines of development that each merge into each other, affording new possibilities through their entanglement. Vygotsky (1987) argued that biological and cultural development are in interaction with each other through the life course of a child. For example, when an infant is biologically able to walk and the cultural practices surrounding the child support their active mobility, then the infant’s actions change because they no longer need to wait for someone to take them to something of interest, they can simply walk to it and actively explore it. In the

cultural development of the child, s/he learns to use the tools of their culture, such as language, music and life rituals. These practices are socially framed and learned, not existing in nature or biology, but developing intergenerationally as a valued cultural practice in families and communities (Monk, 2014). It can be argued that the introduction of digital technologies, potentially puts into dynamic interaction the cultural and biological development of the child, because the tools give access to new possibilities for the child that their biology does not yet allow, such as, being able to physically magnify and digitally photograph/video record on a device in their garden microscopic organisms (Fleer, 2017) or use Google Earth to view their own communities from a plan view perspective (Danby et al., 2016).

Second, in Vygotsky's (1993) study of children with biological disabilities, he argued that when an auxiliary device is used and an alternative developmental pathway created, children are able to access and participate in societal practices. For instance, Braille in printed form and on a keyboard, acts as an auxiliary device to support access to text. Similar to Vygotsky's study of children with disabilities, digital tools and their associated digital pedagogical practices in mainstream settings can potentially act as an auxiliary device because preschool children who could not yet access text independently, because they cannot yet read, can do so through sound activated mobile digital devices and well designed apps. Consequently, young children now have independent access to information (e.g., Google) and gain experiences not previously available to them (e.g., Google Earth). New forms of cultural development open up for children. Theoretically, new possibilities are afforded, even though the concept of an auxiliary device needs more explanation in the context of digital technologies and the cultural development of the child (Bøttcher & Dammeyer, 2016).

Third, capturing the process of the cultural development of the child was theorised by Vygotsky as taking place through social relations. Vygotsky had a particular scientific

explanation that goes beyond social interaction. In summary, he argued that, "each higher form of behaviour enters the scene twice in its development – first as a collective form of behaviour, as an inter-psychological function, then as an intra-psychological function, as a certain way of behaving" (Vygotsky, 1997a: 95). This dynamic is not a simple movement from external (inter) to internal (intra), but rather a transformation of the whole of the child's development and environmental engagement. The child has a new consciousness about their social and material environment that changes the nature of their actions (Vygotsky, 1994). It is beyond the scope of this paper to discuss the associated concepts. Key for the focus of this paper is how the introduction of a digital device creates new developmental conditions. Consequently, the Vygotskian (1997b) concept of imitation is discussed in depth.

Vygotsky (1997b) said, "We would like to promote to the first rank the significance of one of the basic paths of cultural development of the child, which we might call by the generally accepted word imitation." (p. 59). He positioned the concept of imitation not as a copying of actions by a child, but rather as a scientific concept that captures both the child's action and the child's ability to act with meaning. For instance, "Speaking of imitation, we do not have in mind mechanical, automatic, thoughtless imitation but sensible imitation based on understanding the imitative carrying out of some intellectual operation". (Vygotsky, 1997a: 202). Rather, Vygotsky (1997a) drew attention to the cooperation between children in explaining cultural development, when he said, "Everything that the child cannot do independently, but which he can be taught or which he can do with direction or cooperation or with the help of leading questions, we will include in the sphere of imitation" (Vygotsky, 1997a: 202). This is suggestive of help, which theoretically opens up possibilities for conceptualising how digital tools may help children, and therefore digital devices and what they afford can also be within the sphere of imitation. But this theoretical concept is complex, because the researcher needs to determine the relation between what is available to the child

at the same time as observing how the child enters into the available practices (see Hedegaard, 2012), because "…the circle of available imitation coincides with the circle of the actual developmental possibilities (Vygotsky, 1997b: 59; original emphasis). For example, an infant may observe a family playing chess. The child cannot imitate the actions of the players because the child does not yet have understanding of this social practice. Instead, lifting the chess pieces to suck them. A preschool child has greater actual developmental possibilities to role-play the actions of the chess players, but does not yet understand the rules of the game. Therefore, paying attention to both the circle of available imitation (family playing chess) and circle of the actual developmental possibilities (child acting with meaning) is important in this theorisation of the concept of imitation. In the context of this study, this means that both the new practice tradition for digital tool use and the existing preschool practices must be studied together (Knauf, 2016), and special attention be given to how the child enters into the practice traditions, as well as contributes and shapes the existing practices (Knauf, 2016). This dynamic context is challenging to study, however, the concept of imitation does give possibilities for researching digital activity in existing preschool settings. Vygotsky suggested that "imitation is an exceptionally convenient methodological device for research" (Vygotsky, 1997b: 96). In using this concept, it is possible to examine how the digital device and the associated practices might make visible new understandings or capture better the understandings children already have (Vygotsky, 1997b: 96). Key for this study is to understand the practice setting and what the digital tools afford through using the concept of imitation to capture the cultural dynamics and transformative conditions in the practice setting.

Study design

In this paper, the focus is on if and how the digital technologies created new transformative

developmental conditions for the children. To answer this research question, the study focused on the relations between the pedagogy and the children across two preschool sites over two years. In this paper, the data from Site 1 are presented as exemplars of what was learned from the study.

Site and participants

The preschools involved in the research are located in the central city region of Melbourne, Australia. In Site 1 the families and staff are mostly from a European heritage background and hold middle socio-economic income status. In Site 1 in the first year there were 23 children (aged 3.1-4.9, mean age of 4.1) and in the second year 19 children (aged 4.2-5.9, mean age 5.9) were involved in the research. In Site 2 in Year 1 a total of 18 children (3.0-5.8, mean age of 4.8) and in Year 2 a total 13 children (4.7-6.4, mean age of 5.4) participated in the research.

Procedure

All the staff at each site participated in professional development to learn about making digital animations. Site 1 had two iPads, a standalone computer and an interactive white board (Site 1). All teachers appeared to be competent users of digital devices. MyCreate app was introduced for making the digital animation. This was new for them. The teachers (Ruth and Olivia) were inspired by Lindqvist's (1995) Playworlds and selected a series of different stories to inform their play-based program (e.g., Alice in Wonderland, Robin Hood) over the data collection periods[1]. Ongoing digital and pedagogical support was available.

At Site 1 staff were involved in the research for 27.4 weeks in Year 1 and 37.3 weeks in Year 2. The teaching period observed was for 7.1 and 12 weeks respectively, constituting a

[1] [1] The pedagogical characteristics of the Playworld adopted were 1) Selecting a dramatic story; 2) Creating an imaginary situation; 3) entering and exiting the imaginary situation; 4) planning a play inquiry which the children solve; 5) planning the interactions.

total of 15 and 35 field visits. At Site 2 the study took place in Year 1 for 20 weeks and Year 2 for 39.3 weeks. The teaching period was for 4 weeks and 22.3 weeks respectively, constituting a total of 46 and 16 field visits.

Digital observations were undertaken usually with two cameras. One camera was positioned on a tripod to capture the full preschool setting. The other camera was hand held by a research assistant who followed the children as they engaged in the play and learning activities in the preschool. A total of 241.9 hours of digital video observations and 3,279 digital photographs were gathered.

Teacher interviews were undertaken in situ or at specially arranged times through FaceTime/Skype. Planning notes and emails between the teachers and the research team were also gathered. The interviews focused on the planning and reflections of the teaching program. A total of 35.2 hours of digital interview data were gathered.

Analysis

Hedegaard's (2014) holistic conception of society, the institutional practices and person within the activity setting was used to frame the analysis process. This dynamic makes it possible to keep in mind both the values of a particular society, such as wanting graduates of the school sector to be technologically literate, whilst at the same time following how a child enters into the practices traditions of pre-schooling, where the activity setting they enter shapes the child at the same time as the child shapes that setting. The demands of the activity setting, such as making a digital animation of the story book of Alice in Wonderland, create developmental conditions which Hedegaard (2012) has shown to support and develop motivated actions of the child.

The analysis was operationalised through Hedegaard's conception of common sense, situated practices, and thematic/theoretical analysis (Hedegaard & Fleer, 2008). In this study, this meant formulating categories for analysis in relation to both the research question and the concepts informing the theorisation of the problem area (e.g. Vygotsky's concept of development). Specifically, Vygotsky's conception of imitation and his theory of child development were used in a three step iterative analysis process.

Step 1 involved generating categories that allow the concepts to interrogate the data holistically. This is the initial interpretation of the raw data based on the goals of the study. The interpretation is for single situated practices only, such as an activity session on using Google Earth. Specifically tagged were moments where digital tools were being used. As part of this first analytical step, data were then digitally copied from the raw data set and made into clips of single situated practices. This later informed the iterative process of viewing the data many times to allows for additional coding and nuancing of the interpretations. Further digital editing involved cutting single situated practices into a series of interrelated clips, but always tagged to the raw data (i.e., holistic interpretation).

Step 2 involved analysing all the situated practice interpretations across the data set in order to gain a sense of any emerging patterns. This meant looking for multiple examples of each category across data sets which were then digitally filed into folders. Important at this stage was also linking files relationally. Evidence of imitation was tagged and relational links between data folders documented. Figure 1 shows an example of this relational linking. The funnel in the centre captures the pedagogical practices of the playworld.

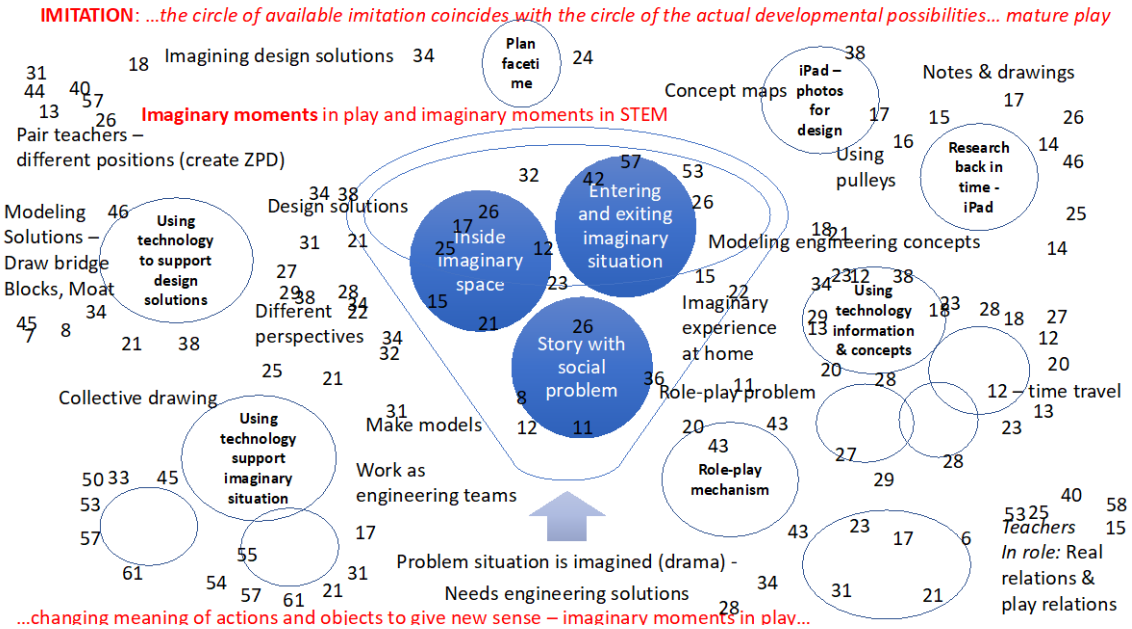

Figure 1. Relational linking and holistic interpretations

Step 3 is a conceptual synthesis and theorisation of the data. Here the synthesis and theorising is in relation to the research question, system of concepts and the relevant literature. These steps are all interconnected and holistic, as is shown in Figure 2 below. In this figure, the three iterative processes described in the three steps above are shown as interrelated, and together they support the answering of the research question of this study.

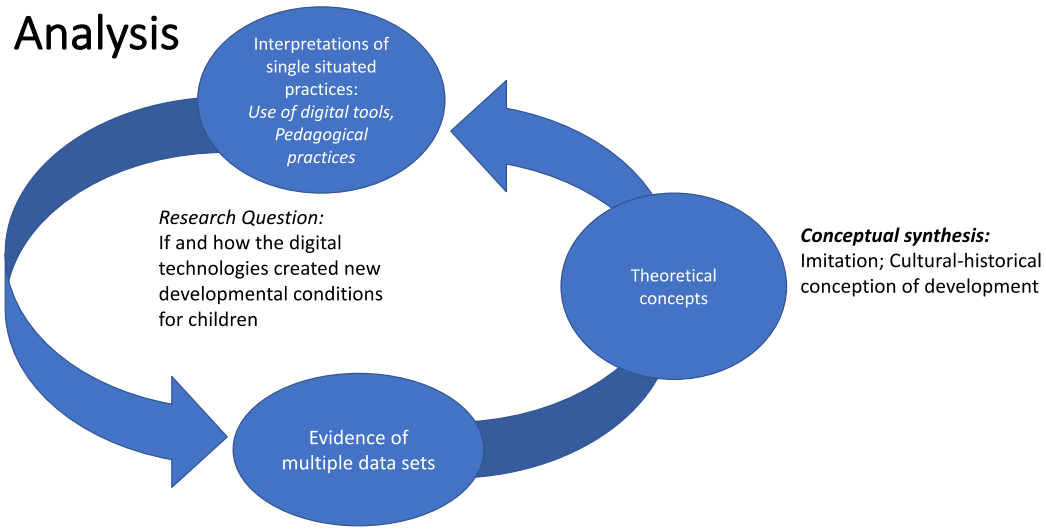

Figure 2. Iterative digital analysis

Findings and discussion

In keeping with a holistic conceptualisation of the study, an overview of the engineering playworld of Robin Hood is given. This is followed by 3 interrelated findings, supported by summary tables and vignettes of typical practices:

- Digitally distributed activity settings
- Coalition of practices
- Digital coadjuvants

Overview of the practice setting

The teaching program for the *Engineering Playworld* of Robin Hood began in the second year of the study, and lasted for the final two terms of Year 2. The teachers selected the story of Robin Hood. Sessions usually featured the story reading of a chapter in the book and entering into the imaginary playworld of Robin Hood in Sherwood forest and role playing adventures associated with the storyline. Children and teachers took a role each time they entered the playworld (e.g., being a dragon, being an engineer, being a researcher, researching back in time). An outdoor wooden cubby with a GoPro acted as the imagined time machine that the children used to go back in time to the story of Robin Hood. Back in time, Bob the Castle Engineer (computer technician in the school) would meet the children to show them engineering principles associated with the castle. The children also brought questions to Bob with several inquiries emerging through the story reading, such as, "How to rescue the dragon from the castle". These adventures back in time usually involved the children documenting their journey, and is shown later, researching and modelling their growing understandings.

(1) Digitally distributed activity settings

One of the central findings of the study was the using of digital devices in a distributed way across the various activity setting in the centre. At the artefact level, the research identified a series of digital tools that were used within the preschool in support of the children's learning: YouTube, iPads, games, AR, GoPro, email, and Google Earth. For the teachers, YouTube, Weebly, email and Skype/FaceTime were regularly used for communicating and program planning.

Table 1 illustrates the type of digital activity setting (column 1), where the tool acts as an auxiliary device in support of a particular action of the children or teachers (column 2), and which appeared to enable new ways of interacting or learning (column 3).

Table 1.
Digitally distributed activity settings

Example of the digital activity setting	**Actions of participants**	**What the activity setting affords**

YouTube	Seek information on time travel, pulleys, simple machines, materials, rope production and testing, etc.	In the moment access to information for children and teachers
iPads	Digitally capture images, review them, and use for in design work	Document and retrieve design work
Game apps	Explore concepts in game format	Complex concepts not directly visible can be explored in child friendly ways
AR	To support collective explanation and retrieval of the group design work of the children	Support the remembering of details of design and engineering principles
GoPro	Simulates security system; acts as a device to program and go into another time period	As a prop in play – changing the meaning of actions and objects in the imaginary situation
Email	During investigations message are send to families	Children and teachers in situ act in time critical ways, interacting remotely with families to support preschool practice
Google Earth	Find and view castles and buildings from a plan view perspective	Change in perspectives - plan view of chosen buildings
Weebly	Teachers shares program with families	School-family communications
Skype	Weekly reflections and planning of practices	Remote teacher support of project

Observations of preschool practices over two years show that the introduction of the digital devices and apps could not be quarantined to a particular activity setting. Rather, the digital tools appeared to be distributed across the broad range of activity settings within the preschool. The unique and distributed digital activity settings summarised in Table 1 is illustrated through an example of an activity setting of group time followed by free play time. In both Google Earth is featured. Teachers introduce the app to the children at group time, and then make the app available during free play time. Some children show familiarity with this app and confidently navigate to find and zoom into a plan view of their preschool.

Activity setting of group time

The children are seated on the floor as a group looking to Ruth who is sitting on a chair holding a mobile device in her hand. She has the screen facing the children showing Google Earth image of a castle in plan view profile. The children had previously been talking about their favourite castles and had mentioned Buckingham Palace. Ruth builds on this by having ready Google Earth image of Bucking palace. Ruth pinches the screen to zoom into the image as she says, "This is Buckingham palace …. I can pass it around later so you can have a play…. from the top". She then signals with her hand a bird flying over the screen of the mobile device and says, "So it is a different perspective. Like a bird flying over the top"… (PH029CGE).

Activity setting of free play time

Three children are seated in front of a large screen computer which shows a map of the southern hemisphere. Jack uses the mouse to open up a tab. He changes the format of the map to a globe. He moves the curser onto the map of Australia and wiggles the mouse to enlarge the image of Australia to show a close up of the state of Victoria. The two children on his left motion over the large screen pinching actions to open the image up and zoom in, as though they are using a small touch screen device. Joseph says, "Now" as he gestures with his hands to zoom closer into the images of Australia. They do not touch the screen, but giggle at each other as they pretend, whilst Jack drives the program to focus on his school and says, "No, you don't need to touch the screen". Ruth joins and says, "Jack I had an idea, can we go in and look at the preschool?". Jack says, "I am doing that"… (PH029:21).

In studying the activity settings in which the digital devices were used it could be determined how new digitally supported actions were being enabled within the particular

activity setting but also across activity settings. Being able to immediately access a plan view of a point of interest (Buckingham Palace) and something well known (their preschool), enabled a different kind of perspective of the world to be available to the children, and under their control (using the app independently). But also, the group time and the free playtime were seamless in their conceptual use of Google Earth as a helpful tool for supporting perspective taking. Different from other studies that focus on the device, this study examined the participants' actions within the activity setting to see how the digital tools changed the nature of the practices in the preschool to afford new developmental possibilities for children.

Although the analysis illustrates how the device acts as an auxiliary tool that is distributed across activity settings of group time and free play time, it still presents the digital technologies as an adjunct to a particular activity setting. What is missing in the analysis of the observed practices, is that it does not yet fully capture the nature of the social and cultural affordances of the digital device and app. We now turn to a discussion of these characteristics.

(2) Coalition of practices

The second central finding of this study was that when the digital devices and apps were conceptualised as part of the social practices in the preschool it became possible to identify a *coalition of practices* which push against a separation of activity settings into digital and non-digital binary. Table 2 below shows how the distributed digital activity setting summarised in Table 1 can be re-read as a dialectical relation between the activity settings. As will be shown, their synthesis affords a coalition of social practices. That is, the digital practices in the centre appeared to be in motion, coalescing around each new social need that arose as part of building the imaginary play. This in turn enabled more complex social practices to emerge with a corresponding new motive orientation for identifying technical solutions for solving social problems in the play. Several interrelated examples of activity settings follow to illustrate coalescing. First, free play time of Georgina and Carol is shown, and second, examples of imagining being in Sherwood forest is presented.

In the first example, free play time featured aspects of visiting Robin Hood back in time, inspiring children to re-imagine and re-create in their imaginary play the social and

technical problems they were exploring. But as is shown, they do so with a mix of artefacts and playful practices.

> *Building a time machine from blocks and making a remote control from collage materials:*
> A group of children are in the block area in the preschool. It is free choice time. Carol and Georgina are working together to build a time machine. Carol places 30cm blocks end to end in a vertical configuration. Georgina steadies the block construction whilst Carol lifts the blocks one on top of the other. At the base of the time machine tower are flat blocks, which act as the platform for the children to stand on. Carol steps on, appearing to test the stability and spatial configuration for supporting a small group of children to time travel. This is later confirmed when Ruth asks Carol, where she travelled to today. Carol responded saying "I was just testing it". …Darlene says, "Why can't you make a real time machine?". Georgina continues to discuss the need for a real time machine, whilst Carol says she needs pipe cleaners and leaves the blocks to work at a table adding pipe cleaners and writing numbers and tiles on her remote control… (PR031, T2).

At the same time, as will be shown in the following two examples of group time, the children and teachers were finding out more about pulleys through imagining themselves going back in time with designs and questions to ask the Castle engineer, but doing so by seeking out more information through watching YouTubes over time.

> *Discussing going back in time – finding out about pulleys:*
> The children are sitting on the mat in the classroom with their teachers. Ruth explains to the children they will go back in time to visit the Castle Engineer Bob. She says, "I've got an idea. We can go back and find Bobby... We could show him our designs. I was thinking we could draw a design, and maybe make a model, of how to break into this treasure room. Because he is so knowledgeable as a castle engineer, he might be able to say, that will work, that bit won't work, have you thought about this, team of engineers?" Brett becomes excited and says enthusiastically, "Can we make our own castle?". Olivia asks Ruth, "So Ruth do we need to know a bit more about this sort of stuff?". Ruth says, "Yes we do. The children are most interested in pulleys"… (PR018).

> *YouTubes - finding out about pulleys:*
> Ruth announces to the group of children seated on the mat, "I went home and I was trying to understand about pullies. I was thinking, what's the difference between a fixed pulley and a moveable pulley?". Brian responds by saying, "Fixed pullies open doors and a moveable pulley opens cranes. Actually, usually the crane that goes up (signals with hand) and down?". Ruth repeats, "It goes up and down…". There is general discussion about the pulley types, and some children move about the room identify fixed pulleys. The conversation continues and the children wriggle forward and face the computer screen. Olivia turns to the computer and starts up the YouTube of pulleys for the children to watch… (PH028H2).

The different activity settings with the range of different practices observed (YouTube, time travel, designing, block play etc) were all coalescing around the social problem. The children had a real need to find out more (motive orientation to learning), so that they could design their grabby hand machine (need to know about pulleys) and design escape routes (so they could go into the castle undetected). The digital tools were not conceptualised in isolation of the practices of the centre and the social problem they were exploring – how to get the treasure out and re-distribute it back to the villagers who needed to buy food.

A multitude of other practices are shown in Table 2 below.

Table 2.
Coalition of practices

New social practices	**Transformative pedagogical characteristic (Teacher perspective)**	**Agentic developmental conditions (Child's perspective)**
Time machine, a time line with technologies from the past and technologies in the present, and technologies of the future	Past-present dialectic	Imagining contrasting time periods to serve an imagined social need
A team of engineers	Working towards collective design, and collective re-presenting/re-visiting through AR	Motive development for collective synchrony and self-regulation
Researching back in time supported by digital tools	Purposeful use of digital tools to support children's documentation	Digital tools as auxiliary device for participation
Researching with YouTubes in support of engineering solutions	In the moment purposeful use of digital tools for gaining information to support solutions	Access to information to support the imaginary situation and/or imagined concepts
Using the pulley systems back in time	Studying engineering principles and learning about the concept of Force	Imagining the drawbridge whilst in reality pulling a rope attached to a pulley

Child initiated play: Models of castles (cardboard and blocks) – playing in them, rest time in them; Designing and making a time machine from blocks and a remote control	Child initiated play as a resource for embodying the imaginary situation of the storyline	Maturing and developing play complexity
Role-playing conceptual understandings at home	Broadening the mediated actions from the centre to the home and back – creating spaces for sharing and incorporating home play practices into the preschool and back	Maturing the play through exploring concepts

Vygotsky (1966) has argued that as children's play matures and becomes more complex, they spend longer talking about the rules of the play than they do enacting the play with their play partners. In line with this theoretical point, this study found that the children spent longer talking about solving the social problems through design solutions for rescuing the dragon, getting the treasure out of the castle to distribute to the villagers, devising a rescue plan, security system, and engineering mechanisms for the collective design of a grabby hand machine. The collective action of being engineers afforded a particular kind of imaginary play, both when inside the imaginary play situation of visiting the caste engineer, and when researching as engineers using digital devices and apps. Further evidence of the motive towards engineering within the storyline of Robin Hood could be seen during free play time, as the example of block building a time machine showed, but there were many other instances of child initiated play, such as, making a moat, draw bridge, and castles to sleep in during rest time. Through a coalition of these practices, there appeared to be both a motive orientation to learning engineering principles and the building of complex imaginary play that demanded a collective orientation of thinking, designing, and acting (playing). It is possible that the digital devices and what was gained through these, supported the maturing

of the children's play (making time machine and remote control, at same time as collectively going into a pretend time machine), which reciprocally oriented the children to learning complex concepts presented in the YouTubes (pulley systems, draw bridges).

(3) Digital coadjuvant

A systematic analysis of the coalition of socially oriented practices (Table 2) revealed multiple profiles expressed in a range of ways. They are summarised in Table 3 as a profile of practices in a play-based program where digital technologies have a multiplier effect. A typical example follows:

> The children are seated on the mat looking at videos and photos previously made, in preparation for going into the time machine to Sherwood Forrest. Olivia says, "You are going, with our iPads… we are collecting evidence of the past". The children excitedly gather their clip boards and the iPads are distributed to small groups. The children enter and exit the time machine with their clip boards and iPads in their hands and run noisely towards the climbing frame where Bob the castle Engineer is waiting for them. Ruth looks to Bob and the children and says, "I have a message for the researchers". Ruth asks who has an iPad, to which two children respond and the children begin documenting the pulley mechanisms. (PH026).

> On another day, the children are seated on the mat with their teachers. There is a large screen next to the mat. The children look to the large screen as Ruth says, "Henry can you come out and present your research". Henry immediately jumps up and goes over to the computer and opens up his folder of photographs taken on the iPad the previous visit to Sherwood forest. Olivia says, "What we are thinking about, as scientists we are thinking: How does it work? What evidence have we collected on, 'How does it

work?'". Henry moves the mouse to click through a series of photos. Later each child retrieves their photographs and use these to support their design work at the tables (PR028 T1 20160913 T Cam 11).

On a subsequent day, Ruth shows the children a pulley she has borrowed from Bob the Engineer, taking it from back in time to the present time. Using an iPad, she shows the children how to take photographs of objects from the different perspectives – a plan view and a front view. The children enthusiastically watch each other take it in turns to photograph a series of objects. Ruth says, "Once you have taken a photograph with the dragon eye and the wolf eye, then you can go over to the design studio". The children begin drawing designs of simple machines (PH038).

The coalition of social practices observed in this extended example of practices across days and activity settings, and noted over the course of the study appeared to be imbued with digital engagement, but the activity settings in which the digital device was used, were also distributed across the preschool. Each activity setting as described in Table 3, does not in itself give a multiplier effect. Rather the multiple effect is observed when the coalition of practices come together to create new transformative conditions for children in preschool settings – as was observed through how researching back in time was a social need and at the same time a technical and conceptual imperative for finding out more. To embody the engineering principles, to work as a team, and to draw upon the researched material for further design work back in the present time, together are different to simple idea of screen time.

Table 3.
Profile of practices in a play-based program where digital technologies act as a coadjuvant

Example of practice	**Concept to capture the practice**	**Explanation**

Social problem drive engineering solutions	Social problem is a *co-efficient* for the engineering solution	Developing a motive orientation to learning concepts
iPads to take photos back in time	Technology acts as an *auxiliary device* for supporting the cultural development of the child	Allowing children to do more than if they have to rely upon their memory.
iPad with photographs discussed and used to support design work	The digital practices were not only interrelated, but acted in a *symbiotic* relation, because the photographs supported new design practices	Photographs capture both the reality of the experience (what is really visible), and the imaginary situation, supporting new design solutions
YouTubes to understand time travel, to understand the concept of Force, to examine properties of materials. Google earth to explore perspectives.	YouTubes supported a *confluence* of what children needed to know and what they had been experiencing physically	Broadening the child's circle of experience and make available/accessible new meanings of everyday practices
Emails to families to broaden the circle of available resources	*Authenticity* of tool use – genuine use of email to support activities	Mirroring in the centre authentic real world technological practices for a real purpose.
Game apps	Digital *replication* of existing imagined concepts and interactivity to explore engineering principles	Mirroring virtually engineering principles in child-friendly digital games
GoPro	Digital *enabler* of new imaginary situations	Children incorporate into the imaginary situations the use of digital technologies to develop the story line
Making, using and playing with technological models (e.g., remote control for time machine, pulleys in draw bridge, designs, living everyday life in a replica castle)	Technologies facilitate new kinds of re-presenting of practices in children's play, but are realised in a modified form through their imagination - *replication*	Children's play actions and narrative make visible in imaginary situations concepts, actions and new practices

The practices evident within and across activity settings move beyond binaries and towards profiles of multiple digital coadjuvants for supporting children's development. A digital coadjuvant is conceptualised as something that facilitates the original preschool practice in ways that modify actions for enhanced effectiveness. In this paper, this means the digital devices and their developmental affordances are conceptualised as having a multiplier effect which amplifies social practices within and across activity settings. It can be argued that the digital devices act as a coadjuvant for enhancing the practices within the preschool and enabling within an activity setting new ways for children to learn and develop. What the study has shown is that there are multiple ways of in which screen time is represented, and a diversity of new transformative conditions for affording the development of children in

preschool settings. This study of just one setting over two years found seven different ways of conceptualising the place of digital devices in preschool settings. They are drawn out in Table 3 and shown as a wheel in Figure 3, as digitally enhanced practices which act together to give a multiplier effect.

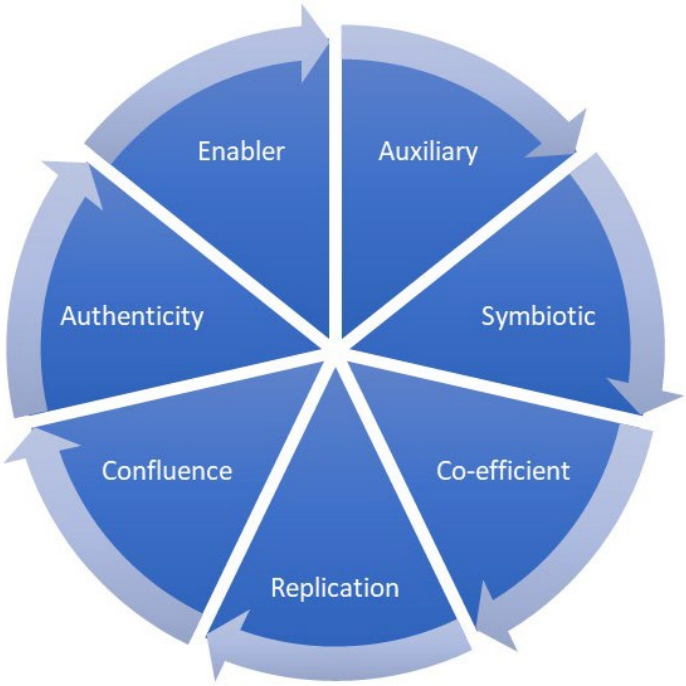

Figure 3. Digitally enhanced practices acting together with a multiplier effect

Conclusion

Digital technology in early childhood education has inadvertently been theorised as a binary between the digital tool and the non-digital activity, despite there being concerns expressed and attempts made to name new practices (Gillen & Kucirkova, 2018). Only some have sought to go actively go beyond this conceptualisation, such as Arnott, Palaiologou, and Gray (in Press, 2018), and Arnott (2017) who has termed the practice as an ecology in order to capture a broader view of digital pedagogy. This study found multiple digital profiles which acted as coadjuvants in play-based programs where digital tools act in ways that modify the actions of the principal pedagogical practices to enhance effectiveness.

It can be argued that technologies act "…as active interventions and transformative forces within the world" (Stetsenko, 2017, p. 30) of the preschool. That is, digital tools act in ways that modify the actions of the principal pedagogical practices in which they are embedded to enhance effectiveness, and coadjuvants appear to positively contribute to new conditions for children's development and learning. This cultural-historical theorisation moves beyond the current binaries and conceptualises practices as profiles of multiple digital coadjuvants for supporting children's development.

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