The integration of the Internet of Toys in early childhood education: A platform for multi-layered interactions

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Abstract

This paper presents findings from an on-going international study of early childhood educators' and children's use of new digital technologies, such as the Internet of Toys (IoToys) and the pedagogic interactions which occur when these artefacts are integrated in classrooms. Based on qualitative methodology, data has been collected in four countries: Australia, Norway, Scotland and England. Data collection includes observations of interactions with IoToys (written and video), multimedia messages (digital images, videos), short written reflections and consultations with the children. Findings across all countries show that IoToys offer a platform for interactions to become multidirectional, multidimensional and multimodal. Examining the interactions in the ecology of the playroom, this study calls for pedagogy involving IoToys to provide a platform for children's rich symbiotic explorations, creativity, collaboration and problem solving.

Keywords: Internet of Toys (IoToys), technology integration, early childhood pedagogy, multidirectional, multidimensional and multimodal interactions, play

Introduction

The integration of digital technologies in Early Childhood Education (ECE) curriculum has posed challenges and dilemmas for staff, parents and children (e.g. Palaiologou 2016; Kewalramani and Havu-nuutinen 2019). This cannot be seen outside of the general debates, which include influential and different ideologies and theories, around what constitutes an ECE curriculum as well as to what extent young children should engage with traditional academic curricula subjects such as literacy and numeracy skills (Wood and Hedges 2016). Since the 1990s in many countries there were attempts at policy level to provide curricula frameworks for ECE. The discourse of what constitutes an appropriate and effective curriculum in relation to digital technologies has raised critical questions about '*what' (content)* should be included and *'how'* (instructions/interactions) it should be delivered or experienced by young children.

These debates more recently have been extended to include the role of digital technologies such as touch-screen and smart toys in ECE curriculum (e.g. Stephen and Edwards 2018). Research examining their integration has begun showing the pedagogical benefits of using technologies as an artefact to enhance the learning environment and encourage creativity and imagination (e.g. Fleer 2018), literacy and numeracy (e.g. Huber, Highfield and Kaufman 2018) and social interactions (e.g. Danby et al. 2018). Additionally, it is well documented that when technologies are integrated and educators engage in high quality interactions with children, this can support, scaffold and extend children's cognitive and imaginative thinking (Yelland 2018) and question-driven inquiry (Hakkarainen and Sintonen 2002).

With the increasing connectivity of digital technologies a new artefact has been the Internet of Things (IoT); physical objects that are connected with the internet and their connectivity is now between things-things, people -things and people-people (Morgan 2014).

Part of the family of IoT are toys that are connected to the internet (IoToys). In contrast to smart toys that are tactile and tangible, but not connected with online platforms, IoToys are physical toys connected with online platforms through Wi-Fi or Bluetooth. IoToys are either anthropomorphised, such as robots or representing animals such as dogs or mice, and equipped with sensors that allows connectivity via the internet with other devices such as a tablet, other toys and/or one to one children (Holloway and Green 2016). In contrast to traditional touch screen technology, IoToys enable children to blur physical environments with online ones where both digital and non-digital elements exist in a fluid synchronous way (Marsh 2017). Research is now emerging examining children's interactions with IoToys when playing (Marsh et al 2019) and examining how the boundaries are blurred for informal and formal learning (Montgomery 2015) through playful learning (Mascheroni and Holloway 2019). This embryonic research is examining the hybrid nature of the toys and how using play based practices can have benefits for children's education (Heljaka and Ihamäki 2018), as well as exploring possibilities for developing children's cognitive capacities such as creativity, inquiry, engineering design thinking (Kewalramani, Palaiologou and Dardanou in press) and how children can be empowered to gain insight by including them in the design process of these toys as experts of their own lives (Yamada-Rice 2019). However, compared to traditional technologies such touch screens, there is still limited pedagogical knowledge and play-based practices of how to integrate IoToys in ECE curriculum and how children and educators interact with them to promote playful learning.

Research needs also to acknowledge that educators may bring different perspectives to their sense making of their curriculum and planning (Wood and Hedges 2016), along with different cultural agendas to underpin policy frameworks and institutional-driven aspirations for young children's learning and development. Although most studies have taken into account play-based practices, they are yet to recognise practices that may encompass digital experiences involving IoToys. Research on how IoToys can be integrated in ECE curriculum is thus under-developed (Stephen and Edwards 2018), under-theorised and more is needed to understand the *what* and *how* IoToys can be integrated into the creation of meaningful learning environments (OECD 2019).

Thus, in this paper, based on empirical research, we attempt to explore how IoToys can be integrated in ECE curriculum and what these pedagogical interactions may look like. The objectives of the study are to investigate:

- what types of interactions exist when IoToys are integrated in the curriculum; and
- whether IoToys can become mediating artefacts for enhancing play and learning.

By examining the integration and the pedagogical interactions within the four countries during play with IoToys this study aims to contribute to the discourse on *how* interactions are shaped in the digital age as well as how educators can best utilise them for playful learning.

Theoretical conceptualisation

To provide focus it is important to unpick what interactions with technologies look like in an ECE context. Plowman and Stephen's (2007, 2008) work on Guided Interaction provided a frame to show how the integration of technology in ECE was possible via proximal (face-to-face) and distal (behind the scenes pedagogic planning) interactions. Such interactions are characterised by: demonstrating, enjoying, explaining, instructing, managing modelling, monitoring, promoting, providing feedback and supporting. However, few studies have carried their work forward with emerging new technologies such as IoToys. Therefore, this paper builds on the work with touch screen technology of Plowman and Stephen (2007) to present evidence of how this scaffolding has progressed with IoToys to offer different properties and affordances, such as the blurring of the physical and online. Also as IoToys have pre-programmed functions research suggests that they enhance socially-mediated playful learning either by the toy providing the content or by the children sharing playful experiences either proximally or through connectivity on online platforms (Chaudron et al. 2017). Moreover due to their interactivity interactions are not only mediated by the toy, but the child can also communicate back to the toy their own personalised experience (Heljaka and Ihamäki 2018; Yamada-Rice 2019).

Within this context we value an approach based on children's rights that promotes the agentic nature of children who are able to participate and have a voice in all aspects of their lives (United Nations 1989). As such, educators and children are positioned as collaborators who share the learning experience, with a common focus of having enjoyment, as they experience resources such as IoToys and consider the child's environment to be comprised of a number of interactions (i.e. with artefacts, agentic beings – peers and guiding adults - and the cultural context) where children co-construct their explorations and learning (Vygotsky 1978). Thus, we question whether IoToys, due to their interactive properties, can become an auxiliary artefact which acts as a mediator, rather an inanimate toy. As has been shown with touch screen technology (e.g. Fleer 2019) when it is placed in the child's environment, amongst other agentic beings, it mediates the conceptualisation of their learning and cognitive development.

Further, within the assemblage of interactions among teachers, children and technology, children conceptualise higher mental functions such as problem-solving dispositions, question-driven inquiry (Hakkarainen and Sintonen 2002), acquisition of speech and language and social learning (Plowman and Stephen 2007, 2008). It has also been shown (e.g. Marsh et al 2019) that children's play and interactions with technology leads to the transformation of the social functions towards individual mental functions – a process mediated by artefacts such as IoToys in this study (Vygotsky 1978). Consequently, we conceptualise the integration of IoToys as a mediator within the "ecology of the playroom" (Plowman and Stephen 2008, 556). We use the concept of "playroom" here to describe not only the indoor environment of the early childhood setting, but the outdoor as well and the interactions that take place within the curriculum framing of each context.

Within that context children's interactions are influenced by different mediating factors such as values, norms, curriculum and resources that form the actual pedagogical practices in educational institutions and shape the interactions that may take place (Hedegaard 2009; Plowman and Stephen 2008). These interactions not only include how a child interacts with the toy, peer interactions and educator interactions, but also respects the agentic nature of children i.e. how the child interacts with the educator and IoToys and how these interactions might be shaped by pedagogical practices.

The context of the study

The four countries in this study have many cultural differences and values that underpin the pedagogy of the education system and their curriculum that impacts on the ecology of the playroom. It is not our intention to present a comparative study, but to investigate the types of interactions that take place when IoToys are integrated in the playroom as mediated artefacts. However, it is important to draw on some similarities in terms of curriculum so we can provide a context for our findings. All four countries have frameworks for ECE that underpin curriculum practices where, as far as outcomes are met, there is flexibility for the educators to interpret and enact the curriculum. Emphasis in all four frameworks is placed on a play-based approach and child-centred practices. In all four countries the integration of digital skills is stressed as an important aspect for developing young children's skills for the 21st century. Table 1 offers an overview of each framework that each country's ECE operates and the level of technology integration.

Table 1 *Overview of ECE Frameworks in each country*

Country	ECE Framework	Ages	Status	Key priorities	Integration of technology
Australia	Belonging, Being and Becoming-The Early Years Learning Framework (EYLF) https://www.education.gov.au/early-years-learning-framework-0	Birth to eight	Statutory	Successful learners; Confident and creative individuals Active and informed citizens	Regarding digital learning, EYLF poses children use media to access information, investigate ideas and represent their thinking and, engage in fun and meaning-making. (Edwards, Straker and Oakey 2018)
Norway	Framework Plan for the Content and Task of Kindergartens https://www.udir.no/in-english/framework-plan-for-kindergartens/	Birth to five	Statutory	Values childhood, wellbeing, friendship and play	National surveys have highlighted the need for integration in the pedagogical practices. Competence requires pedagogical awareness (Jacobsen, Kofoed and Loi 2016).
Scotland	The Curriculum for Excellence Early Level https://scotlandscurriculum.scot/	Three to five	Statutory	Offers children a holistic learning experience to create successful learners, confident individuals, responsible citizens and effective contributors.	Integration is localised to each local authority although the Government position technologies and digital participation as important.
England	Early Years Foundation Stage (https://www.gov.uk/early-years-foundation-stage)	Birth to five	Statutory	Playing and exploring, active learning and creating and thinking critically	Some attempts to integrate technology and research is emerging however in a recent report more work is needed in this sector (Pascal et al. 2019).

Methods

The study builds upon and extends the findings and the qualitative methodology of previous research on IoToys (see Arnott, Palaiologou and Gray 2019a, 2019b; Palaiologou, Arnott and Gray 2019). Across the four countries the IoToys used were integrated to varying degrees

(Table 2). Although there was some degree of familiarity of children with IoToys in the home, no EC settings owned any prior to the start of this study. IoToys across countries varied depending upon available resources and funding and the toys used were specifically bought for the study based on negotiations with the educators of each setting and the potential educational benefits they might have for children. These benefits described by Holloway (2017) are as being engaging, encouraging playful learning (i.e. coding, language, mathematical skills) and promoting collaboration, physicality and imagination, with their pre-programmed functions allowed a blurring between the physical and online environments and content.

Consequently, we report findings on how the interactions are apparent when using IoToys within the ecology of the playroom. The data collection reported here spans from August 2017 to September 2019 with data having been collected with a naturalistic multimethod approach: semi structured interviews or focus groups lasting up to 30 minutes with the educators, observations of interactions with IoToys (narrative and video), multimedia messages (digital images, videos, short written reflections submitted by parents to the researchers) and informal discussions (consultations) with the children. Field notes were used to document the context, routines and procedures, alongside of the rapport building with the children. Table 2 presents the sample in each country and data were collected:

Table 2 *Overview of participants, IoToys integrated and data*

Country	Children's age group	EC setting	Educators (term is used collectively to describe all qualifications in each country)	IoToys used	Data
Australia	17 children from a four year old classroom	Two early learning centres – one early learning centre associated with a private school and one long day care centre	Five educators – three Bachelor of Education in EC degree trained teachers and two co-educators with Diploma in EC.	Robotic toys such as Bee-bot, Botley, Coji, Sphero, Osmo Tangram game app, Quiver – Augmented reality app, littleBits electronic blocks,	Interviews=3 of 30 minutes each Observations=16 hours
Norway	6 children five years old	One kindergarten	One Bachelor of Education EC degree trained teacher, three EC assistants with a one year pedagogical training	Osmo: Coding jam, Awbie and Monster Robotic toys: Dash (xylophone) Dot	Interviews = 1.5 hours Observations = 7 hours Photographs = 263 Voice recordings = 203 minutes with children and educators
Scotland	1 nursery 5 Case Study Children Up to 160 observational children, aged 3-5 years (over 2 years) 20 Staff, 2 key staff focused on technologies (over 2 years)	One local authority run early childhood setting	Varied qualifications. Head of centre undertaking postgraduate study at the time of the study (M.Ed Early Years Pedagogue), remaining staff held undergraduate bachelor degrees, college level childcare	Blue bot Coji Osmo Cubetto Digiscope Marty By Robotical Cosmo Beasts of Balance	Interviews/Conversations with parents and staff = 16 (lasting between 20 and 40 minutes) Video observations = 11 hours Photographs = 193 Conversations with children = 50 images, 2 videos and general field notes across 3 visits. Researchers narrative observations = 5 hours.

			degrees or were modern apprentices.		
England	12 children from years of age up to 5years.	One Early Years Private Setting that followed the mandatory Early Years Foundation Stage Framework to guide their curriculum	Three Educators with two of them having a qualification a year below Graduate Level and one studying for the graduate qualification Early Years Teacher.	Osmo Cosmo Digiscope Coji Beast of Balance Blue Bot	Interviews=six of 30 minutes each Observations= 18 hours

Ethics

The project was guided by principles of participatory research. Children's participation was voluntary, with parents and staff being advised that children's lack of engagement was a reasonable finding and not to force participation. The EECERA Ethical Code of Practice (2015) was followed and approval was granted by relevant university ethics committees and local authorities. Ethical procedures were ensured to seek educators', parents' and children's consent and assent, being mindful that the observation sessions were not intrusive and the consultation questions suited the educators' pedagogical needs and opinions, whilst respecting their professional knowledge and experiences. Pseudonyms have been used for the settings and their respective educators, parents and children. Guided by the work of Chaudron et al. (2017) attention was given to the safety, security and privacy of children's data and no personal information of children was used. The 'Settings Safe Internet Use Policy' was followed at all times.

Data analysis

Data analysis for this paper was based on Hedegaard's (2008) three levels of thematic analysis. First, all video recordings and interviews were watched and interpretation was made, taking different perspectives including those of children and educators within their natural settings and IoToys play environment. Second, situated practice interpretation and sense making of the participants' views, conversations and types of interactions during IoToys play were deciphered. Lastly, through a systematic analysis of the implementation of the IoToys play, themes were emerged in line with our theoretical conceptualisation of interactions amongst educators, children and the IoToys. Further, given the diverse locations of the data collection, each cohort's data was analysed separately before being compiled and analysed across the whole project.

Findings and Discussion

The analysis showed that the context of ECE settings shaped the types of interactions emerging during IoToys play experiences. What we present here is an attempt to recognise the diversity of interactions observed which we link to the pedagogical focus of the context. Firstly, we present the proximal and scaffolded guided interactions led by the educator or "expert other" in relation to technologies. Secondly, we demonstrate how with time, experience and confidence across children's and practitioners' IoToys play these interactions then become multidimensional, multidirectional and multimodal as shown in Table 3:

Table 3 *Types of interactions when IoToys are integrated*

Types of interactions	Description
Guided interaction	The educator, the IoToy or a more experienced peer interact with the child scaffolding the play experience.
Multidirectional	The interactions come from different directions: IoToys' pre-programmed functions and the instructions framed for the children on how it is used;

	Children instruct each other on how IoToy to be used; Educators' explicit interactions and instructions to children on how toy is used; Children instructed educators on how they would like to play with the toy; Children instruct the IoToy on how they would like to play with the toy.
Multidimensional	The interactions move across different platforms: Due to the tactile nature of the IoToys interactions take place in different spaces and places within the playroom, thus the interactions were not static, but there was a blend between the virtual and physical spaces. There is a blend of IoToys and other resources available to the playroom, thus the interactions were intertwined between the functions of the IoToys and other tangible resources to engage in play. Children's 2D artefacts become 3D created artefacts.
Multimodal	The interactions move across modes: Children use multiple modes to convey meaning and share experiences during play with any means available to them (IoToys, physical resources). Each mode available to the children offers affordances that shape their interactions and their meaning making during their play. There is a combination of modes (physical and digital) that moves across physical and digital, so children interact with each other and with these modes to develop play scenarios.

Gaining Familiarity Requires Guided Interactions (GI)

Plowman and Stephen's (2007) work on Guided Interactions shows that digital touch screen technology is characterised by: demonstrating, enjoying, explaining, instructing, managing modelling, monitoring, promoting, providing feedback and supporting. In our analysis of the data, the same functions of GI can be found with IoToys as, for example, in the case of the Norwegian observations where three children are using Osmo Monster with the presence of two pedagogical assistants (Figure 1). That was the first time the group of children were introduced to Monster. Monster provided all the instructions in English language.

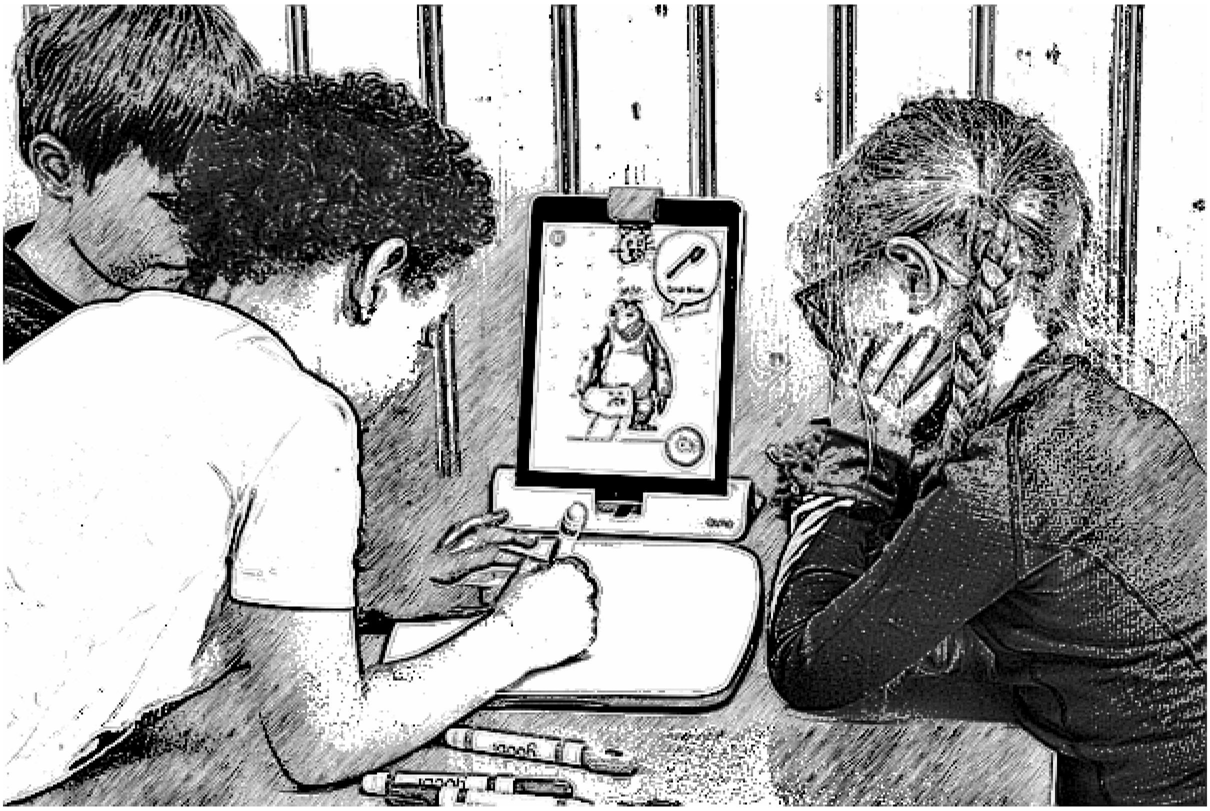

Figure 1 Children collaborating in Osmo Monster.

Two of the participant children (Kristofer and Eirin) are monolingual Norwegians and the third child, Johan is bilingual with English as one of his mother languages and Norwegian as his second language. When the participant pedagogical assistants Marianne and Christina are introducing Osmo Monster to the children, the following dialogue occurs:

-Marianne: [addressing to the children] Wait, wait, you must listen what Monster says

-Christina: What language is he talking?

-Johan: I understand, I understand, he talks English! He says that we will have an adventure

-Marianne: What is an adventure? [Adventure pronounced in English]

-Johan: We will go on a trip.

Kristofer: You must help us understand what he says.

Johan: We will go in a door [door pronounced in English].

Marianne: Does anyone want to draw a door? [door pronounced in English]

The children continued to work together to draw and the multilingual child had the opportunity to translate and interpret the language to English. Initially, only two of the children were actively involved (Johan and Eirin) whilst the third child (Kristofer) was observing and seemed uncertain as he claimed that he could not draw anything other than a potato. After a few minutes Kristofer found motivation to join in and the play transforms through multilayer instructions (as we will show in the next section).

Here we see the need for some children to be more explicitly and proximally supported with IoToys. In this example, the children are being supported by the educator to use Osmo, Monster which then became a group activity where the children showed different aspects of the proximal interactions inherent in GI, such as explaining (Johan explains that the language is English), enjoyment and supporting. During the Monster activity, the multilingual child, Johan, was given the opportunity to demonstrate his competence as an interpreter for the other children. Johan was leading the activity by using his knowledge in English and became the mediator for the play. This experience was positive for Johan as he became the *competent other*. On the other hand, Kristofer had the opportunity to follow Johan's instructions, to observe Eirin and Johan interact with the IoToy before he decided to participate actively. When he felt more confident about the activity he was motivated to participate. Time was important for Kristofer and an aspect for his participation. These child-child interactions made play with Osmo Monster possible for the three children. The role of the educators as a responsive rather than directive influence appears later and, as we will show in the following sections, provided an opportunity for more complex and dynamic interactions to be developed.

The following example from Australia continues this theme and demonstrates the importance of proximal guidance from the educator. During the children's play with the robotic toys (IoToys classified as robotic toys by the educators) the interactions were educator-initiated. Within these interactions, Casie explicitly instructs a group of three children about how the buttons on the remote control work and describes their functions. She purposefully teaches the children how to code using the visual directional cards (Figure 2) and the sequences involved to make the robot (Botley) move.

Figure 2 Educator gives guided instructions.

Using questioning techniques to prompt, Casie makes the children enquire about what sorts of things they would like Botley to do for them and where would Botley like to go for an adventure and encouraged children to manoeuvre him through the obstacle course constructed by the children.

-Casie: It looks like Eddie's reading his cards, have a look at him. He's looking at what his cards are saying and then…Transmit. Go!

-Jo: Transmit [mimicking teacher?]

-Casie: means go straight

-Casie: Did you rubbish bin it Eddie? [Eddie shakes head no]. You press the rubbish bin there. Now you can press the arrows again. [Eddie re-codes Botley].

-Casie: [Pointing to code cards] So is he going? [Botley runs into plastic flag] Here he goes! I wonder if he's going to get a ball?

-Jo: [Squeals] He comes!

In this case, the adult-directed activity becomes an introductory task, a framing activity that allows children to build confidence and competence in using the robot. Children and practitioners need time to explore the resources together before the play can move in multidimensional ways. In the next sections, we show how the interactions are transformed with children and educators' experience and confidence.

Multidimensional, multidirectional and multimodal interactions

Our findings extend the notion of GI as we examined the types of interactions that were exhibited when IoToys are integrated in the curriculum and consequently during children's play. We found that these interactions become multidirectional (interaction come from different directions), multidimensional (interactions move across platforms) and multimodal (interactions move across modes) as shown in Table 3.

In the example from Australia we see how the introduction of an IoToy becomes an auxiliary artefact for children where all the above interactions exist. Initially, when the toy was introduced the interaction was shaped by the adult supporting children and relying on the instructions of the preprogramed functions of the IoToy (demonstrated in the previously on GI), but once children familiarised themselves with the toy we can see all the above types of interactions take place. Children started taking control of their own activity as well as controlling and directing the IoToys. They became designers of the activity using other available resources within the playroom to create multimodal experiences and interactions. Together with the educators, children facilitate the development of their play, exchanging ideas, asking the educator if they can action these ideas and negotiate roles and actions among them.

While building a robot city, children collaboratively made Botley (and another IoToy - Coji) travel through a tunnel constructed with wooden blocks, allowing children to understand play in a multi-modal and integrated environment where technologies are not the defining or central component of an environment, but rather an artefact among many. Just as previous research has shown in the child's life where technologies are now integrated (e.g. Yelland 2018) the robots becomes integrated into the ecology of the playroom where the physical (e.g. tunnel) and virtual (e.g. pre-programmed function of Coji) resources are blended in multidimensional ways to engage in play. The children are able to move between imaginary play where Coji and Botley are given a state of being because of their interactive properties, alongside a physical landscape which children create for them. Here we see children balancing the physical and the imaginary world, thus acting as a mediator, where children's creative imagination is facilitated and brought to life by the robots' interactive capabilities.

Using question-driven inquiry (e.g. "I wonder if Coji can go through the tunnel", "Why did Botley come off track"?), the teacher motivated children in a proximally scaffolded way to consider what other tasks they would like Botley to do for them. Through creative collaboration and continuous problem solving, children created a 'robot city' which had artefacts such as tunnels, café and a farm for all the IoToys they had been interacting with (Botley, Bee-bot and Coji) to live happily (Figure 3). Here we see elements of multimodality as children control the robots in the virtual realm of the iPad (shown in Figure 3 below where the virtual landscape can be seen by the boy holding the iPad), but see it enacted in the physical world of their co-constructed Robot city. It offers two different modalities for the child to experience the life of the robot in this city.

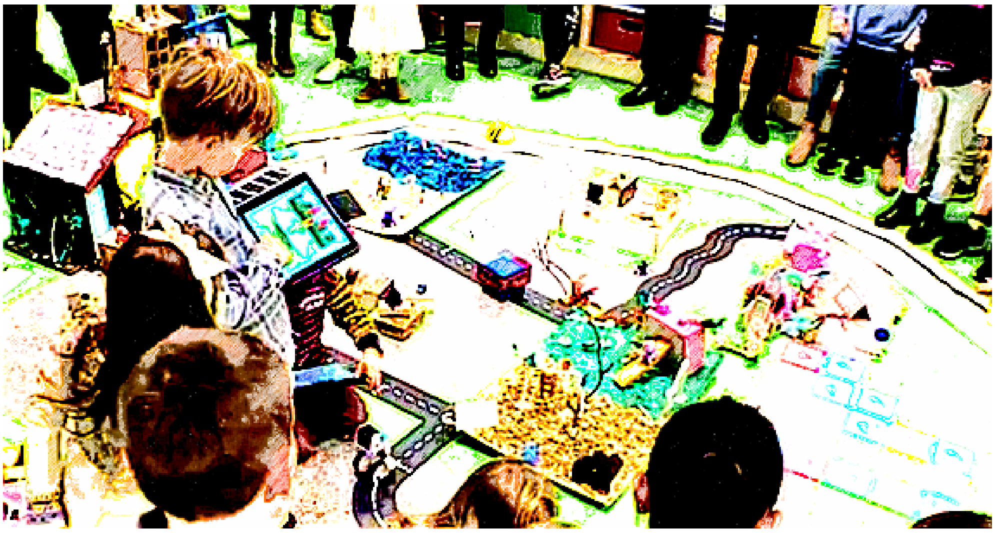

Figure 3 Robot city for all robots to live happily together.

Further, in the above example, we begin to see a movement towards complex interactions between the artefacts, teachers, children and their peers. The educator, Casie, enriched children's learning and provoked their creative thinking. Children socially collaborated with each other in a positive manner and came to a mutual decision about constructing the 'Robot City' as a home for their robots to live. The interactions here started as guided and proximally scaffolded by staff before progressing to multidirectional as the play is framed with suggestions for progression from the toy (in the sense of their functionality), from the children and from the educators. It becomes multidimensional as it blends physical and virtual to facilitate their play in a multimodal way by creating the robot city.

Within their interactions, they reminded each other of the correct functioning of the coloured buttons and helped each other to input the code (GI). When Botley did not follow the given instructions, another child comes and gives a reason why they should recode to manoeuvre Botley out of the tunnel, offering another opportunity for multidirectional interaction as a new member offers suggestions and advice. As such, peer-peer interactions facilitate positive problem solving, where Casie continues to join in as a playmate, inviting and interacting with the children as well to join into the constructions using other resources such as wooden bricks (multidimensional interactions) and conversations to build the robot city and engage in play (multimodal interactions).

In a similar manner, critical interactions between children, practitioners and toys were evident as in the example below from Scotland. Here we see children interacting by supporting each other while the practitioner acts in a responsive manner to support the use of the resource. The resource also has a key role during the play by explicitly guiding the children when they have been successful by offering cheerful and meaningful responses and offering hints and suggestions about how to progress the play to the next task. In the following case we see multidirectional scaffolding interactions between child, artefact and practitioner to support the play.

> *Emilia is using the letter tiles from the game Osmo Words at the table. She is the owner of the technology as she is the only person controlling the activity. A boy (John) operates as spectator sitting in the next seat. A second boy (Nathan) is sitting on the other side acting as participant (not controlling the toy but taking part in the activity by offering suggestions). A cat appears on the screen and the first letter is missing so Emilia has to find the tile with the letter 'c' and place in front of the iPad to play the game. She turns to the practitioner, Denise, who is filming the play and looks for guidance. Nathan makes a c-c-c sound. Emilia looks to Denise and asks "a kicking k"? Nathan replies before Denise can reply "try both ks". Denise confirms, "You try it and see. You give it a go". Emilia returns to the tiles, picks 'C' and places it front of the iPad. The letter 'flies' into the screen, it pings while filling in the full word on the screen and a little figure in the bottom of the screen offers and*

animated celebration to indicate it's the right answer. The two boys smile at Emilia. Denise reaffirms "That one was cat Emilia, cat. So it's a curly 'c', so you got it right, well done"! An animated image appears on screen advising Emilia to clear the 'c' tile from the playing space so the next word can appear. The children continue with the next word on the screen.

Finally, as children develop their confidence and begin to play alone with IoToys we see how these multilayer interactions are becoming multimodal to convey richer meaning where physical and digital modes offer affordances to shape their meaning during their play as in the example from the English data:

Emma (3 years and 4 months) and Peter (3 years and 7 months) are playing with Beasts of Balance (an IoToy where children can construct "beasts" with the help of an application). *They both look at the tablet in order to create their construction with the physical pieces. At this stage both children are manipulating the physical pieces of the toy with the help of the virtual instructions of the pre-programmed toy*

-Emma: "Peter we need a lion and elephant"

Peter looks at Emma with surprise, Emma continues:

-"A lion can scare the beasts and the elephant can carry the beasts away from the lion"

-Peter: "we do not have a lion and an elephant"

Emma gets up picks her colouring book where there are images of a lion and an elephant and with scissors cuts the figures. Then gives the elephant to Peter and she keeps the lion.

Emma still standing and looking at the virtual instructions starts pretending she is a lion and says to Peter:

-"I will chase you"

As Emma and Peter progress with their play, we see that the interactions start becoming multidirectional partially from IoToy and partially from Emma's imagination to develop to multimodal interactions to facilitate their play:

Peter picks up a small dragon figurine from the IoToy and they start chasing each other holding the figures, then Emma proposes that the elephant will turn up and offer to carry all the beasts to save them from the lion.

Then, as the IoToy figurines were 3 dimensional compared to the paper images of the lion and the elephant, the two children transfer their play from the vertical dimension that was offered by the IoToy to the horizontal plane. They put three IoToys figurines on top of the elephant and move all the figurines (IoToy and paper ones) with their hands on the floor horizontally continuing to pretend chasing.

This study is not making claims about a cross-cultural and cross-country comparison, but it investigates how IoToys can be integrated in children's play and, if so, what types of interactions are taking place. An interesting commonality across all countries was the multiplicity of interactions with IoToys in the playrooms. Previous research with touch screen technology (e.g. Plowman and Stephen 2007; Yelland 2018) has shown guided and scaffolded interactions with the child and educator shaping the play with the technology. What is evident from our data due to the tangible and tactile nature of the IoToys, was that these artefacts offer a platform for interactions to become complex and multi-layered. As was shown the interactions do not only originate from the educator or the pre-programmed functions of the IoToy, but also from children themselves as in the case of Emma and Peter, and the Australian example of children co-constructing the robot city.

These types of interactions are blended and identify *how* IoToys can be articulated in the children's play as follows:

1. Child-educator-IoToy: The child leads the interaction with the educator acting and mediating the play as a facilitator and guide (as in the example with Casie and the robot city);

2. Peers-IoToy: Children creatively and socially collaborate to support each other's playful learning (as in the example with Emilia and Denise);
3. Child-IoToys: Children's interactions with the IoToy offers a symbiosis of play experiences (as in the example with Emma and Peter and the robot city construction).

Within these interactions the curriculum can be enriched to provide a context for children's explorations where the IoToys, educators and children interact to co-construct play and learning experiences. Such results help to alleviate concerns raised in previous studies about the integration of technologies in the ECE curriculum (e.g. Edwards 2013; Palaiologou 2016; Mascheroni and Holloway 2017).

When discussing the integration of technology in ECE curriculum into children's play, the two key fundamental questions are the "*what*" to be included and "*how*" to be delivered. These questions are also central to the integration of technology in ECE. The findings of this cross-national study have shown some of the ways the IoToys are integrated in ECE curricula and the types of interactions that take place between the educators and children - particularly how children are using the IoToys in EC playrooms and how educators and children interact with each other fostering multi-layered shared play experiences. As educators' confidence develops with the integration of IoToys in their ecology of the playroom it simultaneously extends children's familiarity with the toys. Children are motivated to engage in child-directed play, thus making the role of the educator as a facilitator and guide. Equally as children familiarise themselves with the IoToys they take control of their explorations and become the experts where they can support each other, mediate educators' experiences and explorations of the IoToys as in the example from Australia where children co-constructed the robot city. This study positions educators and children as collaborators who share the learning experience with a common focus of having a similar level of fun with IoToys as with their experience with physical toys.

Examining the multidimensional, multidirectional and multimodal interactions in the ecology of the playroom, we conclude that when IoToys are integrated they can become a platform for rich symbiotic explorations, creativity, collaboration and problem solving. We propose that IoToys offer a 'symbiotic' resource, in the sense they provide an inter-dependence of play experiences whereby children and educators create a common multimodal platform for children to be creative, collaborate and problem solve together. This then creates a culture for multiple "experts" to guide and support the play.

Conclusions

We conclude that children's shared interactions increasingly call for pedagogy that supports the ecology of the playroom in the digital age. Based on this study's empirical evidence, we frame the integration of IoToys in the ecology of playroom to be seen as reciprocal multilayer interactions among the educators, children and the IoToys. This study demonstrates that shared interactions amongst educators, children and IoToys cannot be understood in isolation, but take into account their multiplicity (educator-child, child-educator, peer-peer, child-IoToys) and how they are experienced together within the ecology of the playroom.

Thus, not only do educators' pedagogical processes mediate children's playful learning (Vygotsky 1978), but peer-peer and child-IoToy interactions spark children's creative, communicative and problem-solving dispositions (Siraj et al. 2017). Our study poses the need for strengthening educators' use of innovative practices and strategies with technologies whereby educators extend the Guided Interaction approach, towards sensitising and learning together alongside children about how to best integrate IoToys for experiential explorations and playful learning. The core to that is to understand the multiplicity of the interactions and how they can be effective for realising IoToys integration in the ecology of the playroom.

Acknowledgments: Sincere thanks are extended to the children, families and practitioners across the countries for allowing us to enter their world and gain a valuable insight into the play. The authors thank the Early Years Academic Community Seeding grant funding granted by Monash University's Faculty of Education for the Australian data collection.

Declaration of interest statement: The authors acknowledge they have no financial interest or benefit arising from the direct applications of their research.

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