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Young Children's Engagement and Learning with the Augmented Reality (AR) Coding App 'Little Red Coding Club'

Research Report

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Executive Summary

This study researched young children's (4-6) engagement and learning with an Augmented Reality (AR) application called ‘Little Red Coding Club’, designed and developed by Twinkl Educational Publishing. The research consisted of four case studies conducted in South Yorkshire early years settings. In total, 30 children aged 4-6 were observed and video recorded using the app in small groups. Six of the early years practitioners involved in the research were interviewed. The video data were multimodally analysed both inductively and deductively. The app’s success in promoting playful learning was assessed using the University of Sheffield’s Makerspace Learning Assessment Framework (adapted from the Bristol Characteristics of Effective Learning) (Kay, Marsh, Hyatt et al., in press). The app’s success in promoting emergent coding skills and knowledge was assessed using the Early Coding Skills and Knowledge Framework. In addition, the interviews with early years practitioners were thematically analysed. The research identified the ways in which the ‘Little Red Coding Club’ app fosters playful learning and early coding skills and knowledge when used by young children (4-6). The key findings of the study are:

1. Engagement with the ‘Little Red Coding Club’ app promotes a range of types of playful learning and early coding skills and knowledge in young children (4-6). Children successfully defined and de-bugged lists of steps (algorithms) to complete tasks within the game. They also created a variety of original texts and artefacts, including visual, on-screen assemblages and oral short stories. All of the characteristics in the Makerspace Play Learning Assessment Framework were observed. All of the early coding skills and knowledge types were observed, with the exception of 11. Identifies loops. In its present form, ‘Little Red Coding Club’ does not afford the creation of loops. In addition to the skills coded in the research, it was identified that ‘Little Red Coding Club’ promoted imaginative oral storytelling. Early years practitioners also perceive that ‘Little Red Coding Club’ promotes a range of skills in young children, in particular social, emotional, physical and cognitive skills.

2. The affordances of the game’s ‘build’ mode particularly fostered certain dimensions of engagement, critical thinking and creativity and design (e.g. exploration of materials and the creative use of materials). The affordances of the game’s ‘story’ mode particularly fostered early coding skills and knowledge types including sequencing, defining algorithms and de-bugging. The game is designed to encourage collaboration through the provision of a ‘two-player’ mode. Technical difficulties prevented research specifically concerning the affordances of the ‘two-player’ mode. However, it was noted that the affordances of the ‘create’ and ‘one-player’ modes both fostered significant social play and learning, but that this was to some extent dependent on the social context of their use.

3. All of the social learning dimensions of the Makerspace Learning Assessment Framework were observed (listening, building on ideas, supporting, effective

collaboration, seek assistance, feedback). In general, the app is designed to afford social learning through the provision of '2-player' mode, which requires both players to understand and communicate the unique abilities of their playable character. This feature was not tested in the present study due to technical difficulties. However, the 'create' and '1-player' modes were found, in themselves, to afford social learning. The children used the app both individually (one child per tablet) and in groups of two (sharing a tablet). There were also multiple examples of a child or group of children playing on one device sharing ideas with a child or group of children playing on another device. There are many instances in the video data of children sharing knowledge and strategies both verbally and through physically demonstrating for another child or children, either by modelling the approach on their own device or tapping their classmate's screen. EYPs echoed these findings, stressing that the game promoted children's collaboration in a relatively spontaneous and relaxed way without a great deal of overt intervention or guidance from adults. In particular, EYPs noticed that children supported each others' learning by pointing out mistakes and modelling the correct approaches, either on their own tablet or by tapping on their classmate's screen.

4. The 'Little Red Coding Club' app promoted a wide range of playful learning and early coding skills for young children (4-6) across all four case studies, i.e. in both Foundation Stage and Year 1. All of the children in the present study (14 girls and 16 boys) exhibited good motivation and engagement with the app, regardless of gender. EYPs identified a range of ways they felt the app could be useful for children with specific physical or education needs. EYPs particularly commented on the utility of the app for children with ASD, limitations in gross motor skills, limited concentration, communication skills or memory.

Section 1: Background to the study

1.1 Introduction

This report outlines the key findings of a co-produced study, developed by academics at The University of Sheffield and Twinkl Educational Publishing (Appendix 1 outlines the project team members). The project was co-produced in that all project partners contributed to the development of the project aims and objectives. The aim of the study was to research young children's (aged 4-6) engagement and learning with an Augmented Reality (AR) application called 'Little Red Coding Club', developed by Twinkl Educational Publishing.

The need for the project was significant, given evidence of growing use by young children of tablets at home (Ofcom, 2018) combined with acknowledgement from many early years practitioners of gaps in their own understanding of how to effectively embed technology in professional practice (Marsh et al., 2017). The study focused on an augmented reality app that is designed to teach early coding skills to young children. Augmented reality (AR) apps like 'Little Red Coding Club' combine play in 'real-world' spaces with screen-based activities provided through apps (Azuma, 1997). This is a potentially rich format for the fostering of playful learning and early coding skills and knowledge. To date, there has been little research in the area of augmented reality learning in early childhood, mainly focused on children's engagement with augmented reality picture books (Yilmaz, Kucuk and Goktas, 2017; Cheng and Tsai, 2014). Coding in early childhood is also an area of increasing interest for researchers (Bers, 2018, 2017), in particular in relation to the increased integration of coding education into early childhood curriculum in a range of countries, including the UK's National Curriculum (Department for Education, 2014). There is currently no evidence of research combining the two (the use of an augmented reality app to promote early coding skills and knowledge in early childhood). This research emphasised how the apps were being used in the context of early childhood settings, in addition to an examination of the affordances (Gibson, 1977) or possibilities created by the design the apps themselves for the promotion of playful learning and early coding skills and knowledge.

The primary focus for this project was the way in which the use of the augmented reality app 'Little Red Coding Club' promotes playful learning. The University of Sheffield's Makerspace Learning Assessment Framework (adapted from the Bristol Characteristics of Effective Learning, Appendix 2) was utilised to identify episodes/ aspects of playful learning. This framework was used because it relates to the creativity and making fostered by an app focused on coding. The study also examined the relationship between children's use of tablets and their emergent coding skills and knowledge. Based on a review of relevant literature, an Early Coding Skills and Knowledge Framework was developed for use in the study (Appendix 3).

1.2 'Little Red Coding Club'

Released in 2018, 'Little Red Coding Club' was designed and developed by Twinkl Educational Publishing. The app was designed to be used by children collaboratively and was designed to teach simple coding skills. The app is a multi-player, interactive AR game designed to quickly and easily teach children to code. It is the world's first educational game to use AR technology to support multiple players on multiple devices. The game was designed to support English National Curriculum requirements and, in addition to teaching coding, 'Little Red Coding Club' was designed to help children develop other key skills, including communication and collaboration. Created around the story of Little Red Riding Hood, the game uses a mobile device to let children work individually or in groups, as they guide Little Red Riding Hood through the forest to Grandma's house. The game uses Augmented Reality to create a 3D forest that comes to life before the player's eyes. The AR space enabled by 'Little Red Coding Club' can be explored by moving the device in any direction, or by moving in and out of the forest landscape. By centering on the popular story of Little Red Riding Hood, the game was designed to be used to help support other subjects and wider schemes of work, with the intention of integrating coding into multiple lessons. The game supports up to 4 devices (2 players, 2 viewers). It is currently marketed as suitable for players age 5+.

When a child opens the 'Little Red Coding Club' app, they are invited to click one of two buttons: 'play' to begin play mode or 'create' to begin create mode. In 'play' mode, they are invited to scan their immediate environment to guide the placement of the augmented reality game board. They are then greeted by a visual of a story book featuring numbered levels (1-10). When they select a number, a short introductory video provides the information needed for the corresponding level. They are then presented with the augmented reality game board and encouraged to press (or drag and drop) directional commands into a sequence board to direct two characters – Little Red Riding Hood and the Woodcutter. 'Play' mode is also available in '1-player' or '2-player' mode. In '2-player' mode, a child or children using a second, third or fourth device can connect to the same augmented reality game board as the first player. Two devices can program characters and up to another two can join as observers. In 'play' mode, they are invited to scan their immediate environment to guide the placement of the augmented reality game board. They are then greeted with a blank game board and invited to create their own (playable) level by dragging and dropping the same range of characters, buildings, decorations and landscape features that are available in the story mode of the game.

1.3 Aims, objectives and research questions

The aims of the study were to research young children's (4-6) engagement and learning with an Augmented Reality (AR) application called 'Little Red Coding Club', designed and developed by Twinkl Educational Publishing. The objectives of the study, as developed by academics at The University of Sheffield and Twinkl Educational Publishing were:

1. To identify the kinds of skills children develop through their engagement with ‘Little Red Coding Club’ in classrooms and early years settings.
2. To examine the social interactions and learning practices that emerge through engagement with ‘Little Red Coding Club’ in classrooms and early years settings.
3. To examine how diverse children (including those with special physical or educational needs) engage with ‘Little Red Coding Club’ in classrooms and early years settings.

The research questions that informed the study were as follows:

i. To what extent does the augmented reality app ‘Little Red Coding Club’ promote young children’s (4-6) playful learning and early coding skills and knowledge?
ii. What are the affordances of the augmented reality app ‘Little Red Coding Club’ that promote young children’s (4-6) playful learning and early coding skills and knowledge?
iii. What characterises the social interactions and learning practices that emerge through engagement with ‘Little Red Coding Club’ in classrooms and early years settings?
iv. How do variables including age, gender and children’s specific physical or educational needs impact on access and use?

1.4 Methodology

The research project was comprised of four case studies across three distinct early years settings in South Yorkshire. In order to ensure anonymity, the settings have been assigned pseudonyms drawn from native wildlife of Yorkshire. Two case studies (1 and 2) were undertaken in Brown Hare Infant School, one in the Foundation Stage and one in the Year 1 class. Case studies 3 and 4 were undertaken in Red Squirrel Primary School (Year 1 class) and Dormouse Infant School (Foundation Stage) respectively. Table 1 outlines the details of the case studies.

Table 1: The four case studies

Case study	Setting pseudonym	Class
Case Study 1	Brown Hare Infant School	Foundation Stage
Case Study 2	Brown Hare Infant School	Year 1
Case Study 3	Red Squirrel Primary School	Year 1
Case Study 4	Dormouse Infant School	Foundation Stage

The research involved two phases of research, which each addressed all of the research questions. These phases were undertaken concurrently.

1.4.1 Phase 1: Video observations of children using 'Little Red Coding Club' in classrooms and early years settings

This element of the research addressed all four research questions. In this part of the study, two researchers used the 'Little Red Coding Club' app, preloaded onto four tablets with a total of thirty children aged 4-6 in early years settings. Key contacts in each setting helped the researchers select and recruit children for participation in the study, as it was intended that the participant sample should include (a) a balance of male and female participants and (b) some children with specific physical or educational needs. Given the project's particular interest in the app's ability to meet the needs of children with particular needs, it was requested that at least one child included in the research in each setting should have some specific physical or educational need. As reflected in the interviews with early years practitioners, the children selected exhibited a range of specific needs. However, it is important to note that at this early stage in children's development, many specific needs are unclear or undiagnosed. In their last full Ofcom inspection (2010), it was reported that the proportion of children with learning difficulties and/or disabilities at Brown Hare Infant School was broadly average. In their last full Ofcom inspection (2011), it was reported that the proportion of children with learning difficulties and/or disabilities at Red Squirrel Primary School was average. In their latest Ofcom report (2009), it was reported that the proportion of children with learning difficulties and/or disabilities at Dormouse Infant School was larger than average.

Table 2: Pseudonym, gender and ages of children who participated in Phase 1

Pseudonym	Gender	Age	Class	Setting
Grace	Female	5	Foundation Stage	Brown Hare Infant School
Bruce	Male	5	Foundation Stage	Brown Hare Infant School
Owen	Male	5	Foundation Stage	Brown Hare Infant School
Elliot	Male	5	Foundation Stage	Brown Hare Infant School
Abir	Male	5	Foundation Stage	Brown Hare Infant School
Arthur	Male	5	Foundation Stage	Brown Hare Infant School
Vicky	Female	5	Foundation Stage	Brown Hare Infant School
Brian	Male	5	Foundation Stage	Brown Hare Infant School
Audrey	Female	5	Foundation Stage	Brown Hare Infant School
Fern	Female	4	Foundation Stage	Brown Hare Infant School
Louise	Female	6	Year 1	Brown Hare Infant School
Cathy	Female	6	Year 1	Brown Hare Infant School

Hadrian	Male	6	Year 1	Brown Hare Infant School
Sam	Male	6	Year 1	Brown Hare Infant School
Isla	Female	5	Year 1	Brown Hare Infant School
Jenny	Female	6	Year 1	Brown Hare Infant School
Grant	Male	6	Year 1	Brown Hare Infant School
Jane	Female	5	Year 1	Brown Hare Infant School
Bennett	Male	5	Year 1	Brown Hare Infant School
Rylan	Male	5	Year 1	Brown Hare Infant School
Esther	Female	5	Year 1	Red Squirrel Primary School
Sadie	Female	5	Year 1	Red Squirrel Primary School
Jeremy	Male	5	Year 1	Red Squirrel Primary School
Adrian	Male	6	Year 1	Red Squirrel Primary School
Emily	Female	5	Year 1	Red Squirrel Primary School
Sandrine	Female	5	Year 1	Red Squirrel Primary School
Dylan	Male	4	Foundation Stage	Dormouse Infant School
Zane	Male	4	Foundation Stage	Dormouse Infant School
Verity	Female	4	Foundation Stage	Dormouse Infant School
Kyle	Male	4	Foundation Stage	Dormouse Infant School

The video recording took place on eight separate days over a period of two months. On each occasion, one of two researchers was present. The app was introduced to children and then the children were recorded using the app. The tablets and equipment were set up in a range of classroom and early childhood education settings, including within the classroom, adjacent rooms and in the playground. The children were directed to ‘Little Red Coding Club’ by the researchers. The researchers had initially been directed to use the app in ‘two-player’ mode in each setting, as well as ‘one-player’ mode and ‘create’ mode. However, technical problems meant that the game was predominantly used in ‘one-player’ and ‘create’ modes. Nevertheless, the children used the app both individually (one child per tablet) and in groups of two (sharing a tablet). Wherever possible, the camera focused on the child’s interaction with the screen. In total, 11 hours, 54 minutes and 21 seconds of video recording was completed. 36 minutes and 34 seconds of these data were excluded from analysis as the video recordings were focused recording other things (e.g. classroom settings), or the videos were too short to be usable (e.g.

under 10 seconds). 11 hours, 17 minutes and 47 seconds of video recording was thus suitable for analysis, which constituted 90 separate videos.

1.4.2 Phase 2: Interviews with early years practitioners

The interviews with early years practitioners addressed all four research questions. Eight visits were made to the three settings over a period of two months. During these visits, early years practitioners participated in interviews in which they responded to questions about the app and how it had been used in their setting, as well as their views on any possible skills they felt the app had promoted. They were also asked for any comments on how they felt the app could be improved as well as how they might embed it in their curriculum planning. Six early years practitioners took part in interviews. All of the participants in the practitioner interviews were female, reflecting the high representation of women in the early childhood education profession. Recent figures suggest that fewer than 2% of staff working in early years and childcare in England are men (Mistry and Sood, 2015). The profiles of the practitioner interviewees can be found in Table 3.

Table 3: Early Years Practitioners who participated in Phase 2

Name (pseudonym)	Gender	Setting	Class
EYP1	Female	Brown Hare Infant School	Foundation Stage
EYP2	Female	Brown Hare Infant School	Year 1
EYP3	Female	Red Squirrel Primary School	Year 1
EYP4	Female	Red Squirrel Primary School	Year 1
EYP5	Female	Dormouse Infant School	Foundation Stage
EYP6	Female	Dormouse Infant School	Foundation Stage

1.5 Approaches to data analysis

The fieldwork generated a variety of data, including video recordings, audio-recorded interviews and fieldnotes.

Deductive and inductive coding and analysis of play sequences

Although the children were selected and encouraged to play specifically with the 'Little Red Coding Club' app, the nature of the research was naturalistic rather than experimental. As such, the children's play with 'Little Red Coding Club' occurred in a variety of complex sequences, often involving more than one child and more than one device. Children joined in, and left the play as they pleased. As such, the video data were analysed as 'play sequences'. A play sequence was defined as a continuous, self-contained sequence of play involving one or more

children, as captured in one or more video clips by the Research Assistants. A new play sequence began when a child or group of children began playing, who had not been playing in the previous sequence. In total, 15 play sequences were analysed. Play sequences varied in length and complexity. The longest lasted 1 hour, 31 minutes and 44 seconds and the shortest lasted 7 minutes and 52 seconds. Play sequences included between 2 and 6 children.

Table 4: The play sequences

Case study	Play sequence	Date	Number of video clips	Total length (HH:MM:SS)	Children involved
1	1a	12/02/2019	2	00:38:45	Grace, Elliot, Owen, Bruce
	1b	12/02/2019	4	00:59:25	Grace, Bruce, Owen, Elliot, Arthur, Abir
	1c	13/02/2019	5	00:48:04	Elliot, Vicky, Bruce, Arthur
	1d	13/02/2019	7	01:31:44	Abir, Brian, Vicky, Bruce
	1e	28/02/2019	6	00:21:10	Abir, Audrey, Fern, Vicky
2	2a	25/02/2019	7	00:45:13	Cathy, Louise, Hadrian, Sam
	2b	26/02/2019	5	00:16:57	Cathy, Louise, Hadrian, Sam
	2c	26/02/2019	4	00:42:29	Jenny, Grant, Isla, Jane
	2d	28/02/2019	6	00:46:32	Cathy, Louise, Hadrian, Sam, Rylan, Bennett
3	3a	01/03/2019	3	00:36:59	Esther, Sadie, Jeremy, Adrian
	3b	01/03/2019	7	00:59:23	Emily, Sandrine, Jeremy, Esther
	3c	08/03/2019	4	00:08:23	Sadie, Sandrine, Jeremy, Adrian, Emily, Esther
4	4a	05/03/2019	8	00:56:23	Dylan, Zane, Verity, Kyle
	4b	05/03/2019	6	00:19:12	Dylan, Zane, Verity, Kyle

	4c	26/03/2019	14	01:19:16	Zane, Verity, Kyle
	4d	26/03/2019	2	00:07:52	Verity, Kyle
	15	**Feb-Mar 19**	**90**	**11:17:47**	**30**

Videos were analysed by drawing on typologies of playful learning and early coding skills and knowledge. Playful learning behaviours were classified using the Makerspace Learning Assessment Framework (adapted from the Bristol Characteristics of Effective Learning). This Framework details 30 characteristics across the five categories of: Engagement; Motivation; Critical Thinking; Creativity and Design; and Social Learning. The definitions applied to playful learning in digital environments (see Appendix 2). This allowed the way in which apps promoted different types of playful learning to be identified. Early coding skills and knowledge types were identified through the use of the Early Coding Skills and Knowledge Framework developed for the present study. This framework was developed based on existing literature concerning coding in early childhood and enables early coding skills and knowledge types to be identified through observable behaviours (see Appendix 3).

Multimodal, deductive analysis of play sequences
Every video clip was multimodally, deductively coded against the the Makerspace Learning Assessment Framework and the Early Coding Skills and Knowledge Framework. Behaviours were coded on the basis of both visual observation and the children's verbal expressions. A total of 90 clips were coded, across 15 play sequences.

Multimodal, inductive analysis of play sequences
Each of the 90 video clips were also inductively, multimodally coded based on phenomena that were visually observed or verbally expressed that lay beyond either of the two frameworks. This coding was arranged into themes. The themes of this analysis are reported below.

Qualitative analysis of interview data
The interview data were transcribed and analysed using thematic analysis (Braun and Clark, 2006). Data were coded both deductively (for skills observed, characteristics of social interactions observed and the engagement of diverse children) and also inductively. This coding was arranged into major themes, which are reported below.

Ethical issues were addressed throughout the study, in line with the BERA Ethical Guidelines (2011). The notion of informed consent underpinned the approach to the research, with an understanding that for young children, assent must be judged through ongoing assessments of the child's body language in addition to other potential markers of discomfort (Dockett and Perry, 2011). If children appeared to be tired, then the interviews/ video recording schedules were adjusted accordingly. Parental consent was sought on behalf of children. The consent of early years practitioners was also sought. Each early years setting was given £100 of vouchers in order to acknowledge the commitment they made to the project.

Section 2: Findings

2.1 Observations with children

2.1.1 Types of playful learning and early coding skills and knowledge the app promoted

The types of playful learning and early coding skills and knowledge the app promoted in each case study are outlined in Table 1.

Table 5: Types of playful learning and early coding skills and knowledge the app promoted

Case study	Types of playful learning the app promoted (based on the Makerspace Learning Assessment Framework adapted from the Bristol Characteristics of Effective Learning)		Early coding skills and knowledge the app promoted (based on the Early Coding Skills and Knowledge framework developed for this study)
Case Study 1: Brown Hare Infant School, Foundation Stage	**Playing and exploring** PE1: Exploring PE3: Sustained interest PE4: Positive attitude PE5: Trying PE6: Unafraid **Active learning:** AL1: Absorbed AL2: Purposeful AL3: Persistent AL4: Goal-setting AL5: Pride in achievements AL6: Meeting challenges **Critical thinking:** CT1: Ideas and initiative CT2: Curiosity and imagination CT3: Problem solving CT4: Extending learning CT5: Novelty CT6: Try and repeat	**Creativity and design:** CD1: Explore materials CD2: Use materials creatively CD3: Trialling CD4: Workaround CD5: Adjusting goals **Social learning:** S1: Listening S2: Building on ideas S3: Supporting S4: Effective collaboration S5: Seek assistance	ECSK1: Directional language ECSK2: Counting ECSK3: One-one correspondence ECSK5: Sequencing ECSK6: Directions ECSK7: Cause and effect ECSK8: Defines algorithms ECSK9: Decomposes ECSK10: De-bugs

Case Study 2: Brown Hare Infant School, Year 1	**Playing and exploring:** PE1: Exploring PE2: Transforming resources PE3: Sustained interest PE4: Positive attitude PE5: Trying PE6: Unafraid **Active learning:** AL1: Absorbed AL2: Purposeful AL3: Persistent AL4: Goal-setting AL5: Pride in achievements AL6: Meeting challenges **Critical thinking:** CT1: Ideas and initiative CT2: Curiosity and imagination CT3: Problem solving CT4: Extending learning CT5: Novelty CT6: Try and repeat	**Creativity and design:** CD1: Explore materials CD2: Use materials creatively CD3: Trialling CD4: Workaround CD5: Adjusting goals **Social learning:** S1: Listening S2: Building on ideas S3: Supporting S4: Effective collaboration S5: Seek assistance S6: Feed back	ECSK1: Directional language ECSK2: Counting ECSK3: One-one correspondence ECSK4: Identifies patterns ECSK5: Sequencing ECSK6: Directions ECSK7: Cause and effect ECSK8: Defines algorithms ECSK9: Decomposes ECSK10: De-bugs
Case Study 3: Red Squirrel Primary School, Year 1	**Playing and exploring:** PE1: Exploring PE2: Transforming resources PE3: Sustained interest PE4: Positive attitude PE5: Trying PE6: Unafraid **Active learning:** AL1: Absorbed AL2: Purposeful AL3: Persistent AL4: Goal-setting AL5: Pride in achievements AL6: Meeting challenges **Critical thinking:** CT1: Ideas and initiative CT2: Curiosity and imagination CT3: Problem solving	**Creativity and design:** CD1: Explore materials CD2: Use materials creatively CD3: Trialling CD4: Workaround CD5: Adjusting goals CD6: Suggesting improvements **Social learning:** S1: Listening S2: Building on ideas S3: Supporting S4: Effective collaboration S5: Seek assistance S6: Feed back	ECSK1: Directional language ECSK2: Counting ECSK3: One-one correspondence ECSK5: Sequencing ECSK6: Directions ECSK7: Cause and effect ECSK8: Defines algorithms ECSK9: Decomposes ECSK10: De-bugs

	CT4: Extending learning CT5: Novelty CT6: Try and repeat		
Case Study 4: Dormouse Infant School, Foundation Stage	**Playing and exploring:** PE1: Exploring PE2: Transforming resources PE3: Sustained interest PE4: Positive attitude PE5: Trying **Active learning:** AL1: Absorbed AL2: Purposeful AL3: Persistent AL4: Goal-setting AL5: Pride in achievements AL6: Meeting challenges **Critical thinking:** CT1: Ideas and initiative CT2: Curiosity and imagination CT3: Problem solving CT4: Extending learning CT5: Novelty	**Creativity and design:** CD1: Explore materials CD2: Use materials creatively CD3: Trialling **Social learning:** S1: Listening S3: Supporting S4: Effective collaboration S5: Seek assistance	ECSK2: Counting ECSK3: One-one correspondence ECSK4: Identifies patterns ECSK6: Directions ECSK8: Defines algorithms ECSK9: Decomposes ECSK10: De-bugs

2.1.2 Key themes from the multimodal, inductive analysis

Skills promoted by different modes of the game

Coding varied in play sequences across the 90 video clips, revealing some general patterns in terms of the types of playful learning and early coding skills and knowledge types promoted by playing in different modes of the game. The children more frequently demonstrated some of the dimensions of engagement, critical thinking and creativity and design when they were playing in 'build mode'. In particular, they were more likely to demonstrate PE2. Transform resources, CT1. Ideas and initiative, CT2. Curiosity and imagination, CD1. Explore materials and CD2. Use materials creatively when playing in 'build mode'. Conversely, they were more likely to demonstrate some of the early coding skills and knowledge types when they were playing in 'one-player mode'. In particular, they were more likely to demonstrate ECSK5. Sequencing, ECSK8. Defines algorithms, ECSK9. Decomposes and ECSK10. De-bugs when playing in 'one-player' mode.

Augmented reality and physical play and exploration

The app's use of Augmented Reality afforded slightly different play to that promoted in relation to a purely digital or purely non-digital game. Some children demonstrated considerable

excitement in exploring both the screens and tablets as physical objects and the game board as perceived or imagined physical spaces. To exemplify, the children demonstrated behaviours such as physically tapping and even physically licking the backs of each other's tablets, but also playing with the affordances of AR, e.g. seeing their classmates 'on' or 'behind' the AR game boards 'in real life'. Several children intentionally positioned themselves in the imagined physical space behind the camera where they imagined the board to be. To give an example, in Brown Hare Infant School (Year 1), Hadrian, who has been interested in the Woodcutter's axe, holds an imaginary axe some distance behind Sam's tablet in the space where he imagines Sam's board must be. Hadrian goes to Sam's screen and peers round to check where the board is, then returns. Holding the tablet, Sam guides Hadrian to where he must stand to be holding the Woodcutter's axe (Play sequence 2d).

The physical challenges for very young children playing 'Little Red Coding Club'

Some children, especially those observed in the Foundation Stage case studies (1 and 4), experienced physical difficulties in playing the game. These difficulties tended to diminish over time. In particular, some children struggled to hold the tablet and play the game (by tapping and swiping the screen) at the same time. Interestingly, the children tended to develop social coping mechanisms to deal with this barrier in the short term. To exemplify, in Brown Hare Infant School (Foundation Stage), Bruce says to Grace:

> *You hold it, and I'll have a go!*
> (Play sequence 1a).

They also tended to become more adept at holding over time. Despite this, they did sometimes complain of feeling physically tired, especially in terms of their arms, and needing to sit down.

Two-player mode and collaborative play

The researchers had initially been directed to use the app in 'two-player' mode in each setting, as well as 'one-player' mode and 'create' mode. However, technical problems meant that the game was predominantly used in 'one-player' and 'create' modes. Both researchers attempted several times to load 'two-player' mode whilst playing with the children and were unable to, despite experimenting with the wifi and bluetooth settings on multiple devices. They fed back that the devices displayed yellow stars instead of loading the boards when they attempted to play in 'two-player' mode. Nevertheless, the children used the app both individually (one child per tablet) and in groups of two (sharing a tablet). There were also multiple examples of a child or group of children playing on one device sharing ideas with a child or group of children playing on another device. In Brown Hare Infant School, Hadrian and Sam have worked out how to program the Woodcutter to cut a tree down, thus providing a bridge over the river. They then verbally share this knowledge with Louise:

It's a tree! You chop down it!
(Play sequence 2a).

There are many instances in the video data of children sharing knowledge and strategies both verbally and through physically demonstrating for another child or children, either by modelling the approach on their own device or tapping their classmate's screen. Interestingly, the children tended to demonstrate a progression from learning to teaching over time. Once some children have gained confidence in the basic coding competences, they begin to teach others. In Brown Hare Infant School (Year 1) play sequence 2d, Cathy and Louise have been playing with the app for some time when Rylan and Bennett come over to join in. Cathy holds her tablet up for Rylan to see and begins to explain how to play ('you can keep going by pressing that'). Meanwhile, Louise stands behind Bennett, watching and guiding his early play ('no, you need one more forward'). Within the present dataset, this type of collaboration appears to be less common when each child in the group has his or her own device. The children more frequently demonstrated some of the dimensions of social learning when they were playing together on a device or collaborating across devices.

Child-device promoted skills versus adult pedagogical intervention
Many of the skills identified above were exhibited by the children in their solo or peer-based engagement with the app. However, the promotion of others would clearly require suitable pedagogical intervention from an adult. CD6. Suggesting improvements was observed in only 2 of 90 video clips. This aspect of creativity and design was coded when a child makes suggestions as to how an artefact could be improved. This aspect was observed in Red Squirrel Primary School in play sequence 3c and 3b. In both cases, an adult invites the children to reflect critically on the game. Jeremy, who has been very excited by the wolf, suggests that the wolf should be a playable character. ECSK7. Cause and effect was observed in only 18 of 90 video clips. This aspect of early coding skills and knowledge was coded when a child demonstrated understanding of cause and effect (if… then…). This aspect was observed in a number of play sequences, including play sequence 2c in Brown Hare Infant School (Year 1). In this example, the researcher is encouraging Grant and Jenny to talk about what they have been doing with the app. Grant and Jenny are then able to articulate cause and effect in relation to their coding sequence, explaining that the Woodcutter must go first because the tree must have been cut down to create a bridge before Little Red Riding Hood is able to cross the river. The children tended to verbalise more directional language when their class teacher worked with them during the research, in addition to the researcher. They also tended to count ordinals aloud more frequently when their class teacher was present.

Counting versus 'visualising' the route
The children across the case studies showed a clear ability to count, since they put together sequences of varying lengths to successfully complete levels. However, they demonstrated a variety of techniques for deciding how many commands were needed in a particular sequence. Whilst some counted aloud, many followed the white 'guide' lines that appeared on screen, which helped them to visualise where their character would progress to when they pressed go, based on their current sequence. On the one hand, this provided a fantastic mechanism for

increasing their confidence. On the other hand, it did not support traditional counting using ordinals. Introducing a later level or mode in which the white guide lines gradually disappear might more effectively promote counting using ordinals. In play sequence 4a in Dormouse Infant School, Kyle's teacher is present during the research and asks him questions that prompt him to count aloud. It is interesting to note that in play sequence 4b, Kyle's teacher has left the room, but Kyle's continues to count aloud in ordinals when he creates a sequence on his own.

Creativity and oral storytelling

Once some of the children had gained confidence in the basic coding competencies, they began to demonstrate imaginative play and elements of oral storytelling that incorporates aspects of their learning. The children use elements of their learning within their storytelling in multiple imaginative ways. At Brown Hare Infant School (Year 1), during play sequence 2d, Hadrian and Sam have been creating a level that looks like a maze in 'create' mode, by placing paths on the grass. They proceed to co-construct a narrative about a maze based on their creation. Little Red Riding Hood, they suggest, can hide and surprise the wolf, biting him when the time comes to attack. At Red Squirrel Primary School, during play sequence 3b, Esther has designed a level with a good deal of water in 'create' mode. She says that she is creating an island in the centre of the water that will be safe from the wolf, and begins to add multiple food items onto her 'island', where the wolf can't get them.

2.1.3 Summary

This analysis indicates that engagement with the 'Little Red Coding Club' app promotes a range of types of playful learning and early coding skills and knowledge. Children successfully defined and de-bugged lists of steps (algorithms) to complete tasks within the game. They also created a variety of original texts and artefacts, including visual, on-screen assemblages and oral short stories. The research was limited to play related to use of the 'Little Red Coding Club' app, so it is impossible to know how the children extended this playful learning in the classroom and at home. All of the characteristics in the Makerspace Learning Assessment Framework were observed. All of the early coding skills and knowledge types were observed, with the exception of ECSK11. Identifies loops. Identifies loops refers to children identifying repeated patterns in code that could be replaced by a loop. In computer programming, a loop refers to a sequence of instructions that is repeated, for example, for a specific number of times. In its present form, 'Little Red Coding Club' does not afford the creation of loops. Users can tap or drag and drop single commands into a sequence and remove them individually by dragging and dropping or erasing an entire string. Once programed and played, a user could press play again to repeat the sequence, but could not command the repeated sequence to run a specific number of times in one go. This could be a potential area for new content development, although it should be noted that identifying loops is not part of England's National Curriculum for computing in Key Stage 1.

There was a range of evidence, therefore, that suggested that the 'Little Red Coding Club' app promoted a wide range of playful learning and early coding skills for young children (4-6). It is interesting to note that these skills were demonstrated across the four case studies in

Foundation Stage and Year 1, suggesting that the app promoted a wide range of playful learning and early coding skills for children as young as 4 years old.

2.2 Interviews with early years practitioners

2.2.1 Skills promoted by 'Little Red Coding Club'

Early years practitioners described a range of skills they felt were promoted by the 'Little Red Coding Club' app. They tended to describe these skills in terms of social, emotional, physical and cognitive domains. Early years practitioners focused particularly on the social dimensions of skills promoted, describing children working as a team, taking turns, sharing and collaborating, as one EYP described:

> *The turn taking, the sharing, those collaborative skills really shone through, which I thought was really positive as well, which not necessarily would in every other setting.* (EYP 6, Dormouse Infant School).

The early years practitioners also raised some of the themes identified in the inductive, multimodal analysis of the child observation data. In particular, they noted that the way that the children engaged with 'Little Red Coding Club'. When two children shared a tablet, it encouraged them to work together in partnership. However, even when children were working one to a tablet, the EYPs noted many instances of children looking over to help each other out verbally when they were stuck. Sometimes a child who appeared to have grasped a particular concept or skill more rapidly would physically help another child by physically showing them how to do something or demonstrating it on his or her tablet. In common with the analysis of the child observation data, the EYPs also commented in interviews on the partnership working they have observed that was encouraged by the children's occasional inability to both hold the tablet and operate the game by tapping the screen at the same time. In such instances, one child would hold the tablet whilst another tapped on the screen.

The EYPs described a range of emotional skills promoted by the 'Little Red Coding Club' app, in particular raised confidence, resilience and increased concentration. They particularly praised the app's encouragement of trial and error approaches, noting that children tended to keep trying until they succeeded (another finding in common with the analysis of the child observations). Of particular interest is the finding that early years practitioners felt that the 'Little Red Coding Club' app promoted higher levels of social and cognitive engagement in certain types of children. EYPs noted that children who were ordinarily more reserved became more animated and excited and were able to chat with their fellow students more than they normally would have done. They also suggested that the app seemed to capture the attention of children with differing concentration abilities - from those who ordinarily concentrated well to those who ordinarily struggled very much to concentrate. EYPs also commented on the physical skills they felt the app promoted, in particular, spatial awareness.

Finally, EYPs commented on the cognitive skills they felt that the 'Little Red Coding Club' app promoted. In this domain, they commented frequently and enthusiastically on coding and computational skills, as well as mathematics, storytelling, comprehension, problem-solving, creativity, decision-making, language and using directional language.

2.2.2 Characteristics of social interactions in relation to 'Little Red Coding Club'

Early years practitioners discussed social interaction a good deal in relation to the skills promoted by 'Little Red Coding Club', as discussed above (working as a team, taking turns, sharing and collaborating). They observed that the game promoted children collaborating in a relatively spontaneous and relaxed way without a great deal of overt intervention or guidance from adults. In particular, EYPs noticed that children supported each other's' learning by pointing out mistakes and modelling the correct approaches, either on their own tablet or by tapping on their classmate's screen. One factor that needs to be taken into account is the characteristics of the children themselves, some of whom engaged in these behaviours less than others.

Of particular interest was the social interaction that occurred between the children and the game (child-game interactions) and between the children, game and other children (child-game-child interactions. The app's use of Augmented Reality afforded slightly different play to that promoted in relation to a purely digital or purely non-digital game, as one EYP described:

> *Because they're trying to actually immerse themselves into the actual place aren't they, which is great.*
> (EYP 4, Red Squirrel Primary School).

This finding is also in common with the analysis of the child observations.

2.2.3 'Little Red Coding Club' and engaging and promoting skills in diverse children

EYPs articulated a range of opinions in relation to 'Little Red Coding Club' and engaging and promoting skills in diverse children. These were predominantly positive, although one EYP (EYP 6, Dormouse Infant School) raised a concern. EYP 6 noted that playing the game seemed difficult for one child who struggles particularly with gross motor skills and that she had ended up holding the tablet for this child, so he could focus his attention on the gameplay on screen. However, the same EYP also noted that the game promoted language skills in the same child.

EYPs identified a range of ways they felt the app could be useful for children with specific physical or education needs. One noted that the game could be very motivating for children with limited motor skills for whom writing is difficult:

> *Those children who have greater motor issues, so find writing really difficult, they can achieve success with just the touch of a button; and they can achieve their learning without having to put pen to paper, which sometimes children find incredibly difficult.*
> (EYP 2, Brown Hare Infant School).

The same EYP had been involved in the fieldwork on the previous day, and had spent some time observing a child with Autistic Spectrum Disorder and social communication difficulties. She felt that the app had helped the child to communicate with his peers:

> *You worked with a child with ASD yesterday and he has social communication difficulties, yet using the app he was communicating with his peers, which was really lovely to see.*
> (EYP 2, Brown Hare Infant School).

One EYP felt that the game could be particularly helpful to students she worked with who had memory problems and struggled to remember areas of learning that came up infrequently on the curriculum:

> *Some do [forget], it tends to be children with special needs, and if they have got additional needs this would be lovely because it's like an easy gentle way in to think 'can you remember this'. And you tend to remember a game you've played.*
> (EYP 3, Red Squirrel Primary School).

As noted above, EYPs also suggested that the app seemed to capture the attention of children with differing concentration abilities - from those who ordinarily concentrated well to those who ordinarily struggled very much to concentrate.

2.2.4 Current and future curriculum needs for apps like 'Little Red Coding Club'

The EYPs interviewed in the present study perceived a need for apps like 'Little Red Coding Club' in relation to meeting particular EYFS and curriculum targets across multiple areas (language, computing, social skills, mathematics etc.) A response from EYP 2 successfully represents this perspective on the merits of 'Little Red Coding Club' in relation to the pressures felt by EYPs in terms of complex EYFS and curriculum targets:

> *What we need is as many cross-curricular links as possible with having the curriculum.... having to fit so many things in. So if this could cover some of our computing curriculum, trying to get children to use the vocabulary such as algorithm and debugging, that would be a great asset. So having some way of getting that kind of language into this program, because they are building algorithms and they are debugging their programs all the time, would be a great help.*
> (EYP 2, Brown Hare Infant School).

EYPs focused not only on hitting current targets, but also on the wider picture in terms of children's futures. Several of the EYPs discussed the skills that they expected the children might need in their future careers, perceiving coding and problem solving in particular as potentially useful:

> *It's like you are training children to do a job that might not have even been invented yet. I loved that. I thought 'yes, that is it, we're not teaching them to be doctors, nurses,*

teachers, whatever, it's like we don't even know what they're going to be. So I think we need to adapt more and I think a lot more coding and a lot more computer skills.
(EYP 3, Red Squirrel Primary School).

2.2.5 Material and human resource implications of 'Little Red Coding Club'

EYPs were, however, cognisant of the practical needs relating to access to opportunities like engaging with 'Little Red Coding Club', including sufficient tablet devices, a reliable WiFi connection and space for children to move around while they play it. Some also felt that adult support was important or essential for children's successful engagement with the possible learning opportunities offered by the game:

I think for something like this, especially with our kids, it's a case of having that adult interaction, for it to be used effectively and purposefully, and I think that's the key.
(EYP 6, Dormouse Infant School).

In terms of scaling up use of the game, this EYP highlighted the challenge of staff resourcing in relation to supporting a whole class of children:

On a whole class level that would not be accessible I don't think, especially not in a Foundation Stage, because it would be so hard to facilitate it. I think more than anything, at the end of the day, there's only two members of staff.
(EYP 6, Dormouse Infant School).

This highlights a potential challenge for wider use of 'Little Red Coding Club' in early years settings in the UK. It is worth noting, however, that the issue may be less problematic in contexts outside of the UK, where class sizes are often smaller. The question of resource could also further inequalities if some settings struggle to access tablet devices. Despite this, EYP 6 was positive about wanting to embed the use of 'Little Red Coding Club' in the setting, suggesting several weeks of supported small group work external to the main classroom.

2.2.5 EYP recommendations for improvements

The following ideas for improvements were suggested by EYPs:

- Providing multiple different fairy tales or traditional stories.
- Creating a wider variety of objects to collect in addition to apple, bottle, etc.
- Designing the Woodcutter and Little Red Riding Hood to ask each other questions, or perhaps ask the children to pick up different things.
- Providing more instructions - perhaps in audio form.
- Enabling children to create another 'scene' in create mode (perhaps outside the Little Red Riding Hood story).
- Creating a prize at the end of the game, when the children successfully complete all of the levels.
- Including different and more advanced tasks for older children.

- Including the language that they are required to cover in the computing national curriculum for key stage 1 (for example, ‘algorithms’ and ‘debug’) into the directions text displayed at the beginning of the game.
- Incorporating a lanyard to support holding the device and improve accessibility for children with limited motor skills.
- Providing shorter, alternative paths or levels for younger children to prevent loss of interest if they are struggling on the longer, more complicated paths.

2.1.3 Summary

The interviews with early years practitioners undertaken within the present study indicate that ‘Little Red Coding Club’ has been very positively received by both young children (4-6) and their teachers. Early years practitioners perceive that ‘Little Red Coding Club’ promotes a range of skills in young children, in particular social, emotional, physical and cognitive. Early years practitioners stressed an increased appetite for resources that facilitate the teaching of coding in early years settings, and felt ‘Little Red Coding Club’ combined this function with multiple other areas of the National Curriculum. In addition, most felt that ‘Little Red Coding Club’ had particular affordances that promoted skills in diverse children with specific physical or educational needs.

Nonetheless, the EYPs were mindful of the practical challenges in terms of resourcing equal access to tablets in early years settings. They also raised a note of caution around the human resource implications.

Section 3: Conclusions and recommendations

3.1 Summary of key findings

This study has identified the ways in which the 'Little Red Coding Club' app may foster playful learning and early coding skills and knowledge when used by young children (4-6). The key findings of the study are summarised briefly in relation to each of the original research questions that underpinned it.

(1) To what extent does the augmented reality app 'Little Red Coding Club' promote young children's (4-6) playful learning and early coding skills and knowledge?
Engagement with the 'Little Red Coding Club' app promotes a range of types of playful learning and early coding skills and knowledge in young children (4-6). Children successfully defined and de-bugged lists of steps (algorithms) to complete tasks within the game. They also created a variety of original texts and artefacts, including visual, on-screen assemblages and oral short stories. All of the characteristics in the Makerspace Learning Assessment Framework were observed. All of the early coding skills and knowledge types were observed, with the exception of ECSK11. Identifies loops. In its present form, 'Little Red Coding Club' does not afford the creation of loops. In addition to the skills coded in the research, it was identified that 'Little Red Coding Club' promoted imaginative oral storytelling. Early years practitioners also perceive that 'Little Red Coding Club' promotes a range of skills in young children, in particular social, emotional, physical and cognitive skills.

(2) What are the affordances of the augmented reality app 'Little Red Coding Club' that promote young children's (4-6) playful learning and early coding skills and knowledge?
The 'build' mode of the game enables children to design their own levels using a range of digital elements such as paths, water, characters and objects. The affordances of this mode particularly fostered certain dimensions of engagement, critical thinking and creativity and design (e.g. exploration of materials and the creative use of materials). The 'one-player' mode of the game encourages children to code sequences to maneuver a character or characters across an augmented reality game board. The affordances of this mode particularly fostered early coding skills and knowledge types including sequencing, defining algorithms and de-bugging. The game is designed to encourage collaboration through the provision of a 'two-player' mode. Technical difficulties prevented research specifically concerning the affordances of the 'two-player' mode. However, it was noted that the affordances of the 'create' and 'one-player' modes both fostered significant social play and learning, but that this was to some extent dependent on the social context of their use.

(3) What characterises the social interactions and learning practices that emerge through engagement with 'Little Red Coding Club' in classrooms and early years settings?

All of the social learning dimensions of the Makerspace Learning Assessment Framework were observed (listening, building on ideas, supporting, effective collaboration, seek assistance, feed back). In general, the app is designed to afford social learning through the provision of '2-player' mode, which requires both players to understand and communicate the unique abilities of their playable character. This feature was not tested in the present study due to technical difficulties. However, the 'create' and '1-player' modes were found, in themselves, to afford social learning. The knowledge required in the game progress sequentially through the levels. Although short visual and verbal tutorials illustrate some of the main principles of the game, there are things the user must work out for themselves through trial and error. This appears to afford a good deal of social learning, as children seek and offer strategies for meeting the increasingly difficult challenges of each level with their peers. The children used the app both individually (one child per tablet) and in groups of two (sharing a tablet). There were also multiple examples of a child or group of children playing on one device sharing ideas with a child or group of children playing on another device. There are many instances in the video data of children sharing knowledge and strategies both verbally and through physically demonstrating for another child or children, either by modelling the approach on their own device or tapping their classmate's screen. EYPs echoed these findings, stressing that the game promoted children's collaboration in a relatively spontaneous and relaxed way without a great deal of overt intervention or guidance from adults. In particular, EYPs noticed that children supported each others' learning by pointing out mistakes and modelling the correct approaches, either on their own tablet or by tapping on their classmate's screen.

(4) How do variables including age, gender and children's specific physical or educational needs impact on access and use?

The Little Red Riding Hood app promoted a wide range of playful learning and early coding skills for young children (4-6). It is interesting to note that these skills were demonstrated across the four case studies in Foundation Stage and Year 1, suggesting that the app promoted a wide range of playful learning and early coding skills for children as young as 4 years old. The research included a balanced sample in terms of gender (14 girls and 16 boys). All of the children in the present study exhibited good motivation and engagement with the app, regardless of gender. Finally, EYPs identified a range of ways they felt the app could be useful for children with specific physical or education needs. EYPs particularly commented on the utility of the app for children with ASD, limitations in gross motor skills, limited concentration, communication skills or memory. There are multiple affordances of the app that support learning for children with specific physical or education needs. As EYPs noted, the app makes successfully coding a sequence achievable with only a few taps on a screen, making programming accessible for children with limited gross motor skills. The EYP interviews pointed towards an understanding that the app provided something of an engaging 'third party' focus for children with communication limitations, who seemed to communicate more enthusiastically and successfully with their peers in relation to the game than during traditional classroom activity. The EYPs comments in relation to memory may also relate to the app's use of a very familiar and much retold fairy tale.

3.2 Significance of the study

The study makes a contribution to the field in a number of ways. First, it provides knowledge about the ways in which young children's use of an augmented reality app may promote playful learning and early coding skills and knowledge. It identifies the specific skills promoted, as well as identifying ways in which they are socially supported by peers and adults. This has important implications for pre-school practice, in addition to offering useful guidance for parents and app developers. Second, the study offers an insight into the use of an augmented reality app by 4-6 year-olds for the specific purpose of teaching early coding skills and competencies. This is an under-researched area and the data therefore contributes to the development of insights into how 4-6s use such apps in the context of early years settings.

Third, the project makes a contribution to methodology in this field in that it developed a framework for assessing the early coding skills and knowledge of very young children, based on a review of relevant literature. Finally, the study makes a contribution to an understanding of the way in which applied research might benefit from being undertaken as a collaboration between university, school and industry partners.

3.3 Recommendations

The study has led to a number of findings that require further action in the years ahead. The following recommendations are made:

1. The work of app producers who develop apps for the pre-school market should be informed by those design aspects of apps that promote playful learning and early coding skills and knowledge for young children (4-6).

2. Where possible, all early years settings and schools should enable children's access to tablets in order that children that do not have access to them at home are able to develop relevant skills and knowledge.

3. Further guidance on how to use tablets and how to choose and successfully support learning with apps that promote playful learning and early coding skills and knowledge for young children (4-6) should be developed for early years practitioners.

4. It would be beneficial for further research to be undertaken in a number of areas. In particular, further research into the social dimensions of young children's engagement with apps that teach coding skills and knowledge, given the very limited research in this area.

5. This study provided evidence that augmented reality apps can facilitate playful learning and early coding skills and knowledge. Children move across the online/ offline, 'real' and virtual, digital and non-digital boundaries with ease. As new technologies in this area continue to

emerge, further research needs to examine the implications for children's playful learning and early coding skills and knowledge and it would be beneficial for this research to be conducted by academic and media industry partners, given the knowledge and skills each party could bring to the collective endeavor.

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Appendices

Appendix 1: Project partners

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Appendix 2: Makerspace Learning Assessment Framework (Kay et al., in press) (adapted from the Bristol Characteristics of Effective Learning)

Category	Definition
PE: Playing and Exploring	
PE1: Exploring	Child uses their senses to explore and make sense of their world.
PE2: Transforming resources	Child transforms resources.
PE3: Sustained interest	Child demonstrates sustained interest in the task.
PE4: Positive attitude	Child demonstrates a 'can do' attitude.
PE5: Trying	Child is eager to try out new ideas (rather than just staying with what they are familiar with).
PE6: Unafraid	Child is unafraid to make mistakes and work outside their comfort zone.
AL: Active Learning	
AL1: Absorbed	There are times when child is absorbed in their own learning.

AL2: Purposeful	Child demonstrates a sense of purpose.
AL3: Persistent	Child shows persistence – not going up even though it means starting again.
AL4: Goal-setting	Child is able to set their own goals.
AL5: Pride in achievements	Child demonstrates pride in their achievements.
AL6: Meeting challenges	Child enjoys meeting their own challenges.
CT: Critical thinking	
CT1: Ideas and initiative	Child has their own ideas and uses their own initiative when planning designs.
CT2: Curiosity and imagination	Child demonstrates curiosity, imagination, spontaneity and innovation.
CT3: Problem solving	Child uses strategies to solve problems or challenges in their designs.
CT4: Extending learning	Child challenges and extends their own learning.
CT5: Novelty	Child does something different rather than follow what someone else has done.
CT6: Try and repeat	Child tries out and repeats their ideas to see if they work.
CD: Creativity and Design	
CD1: Explore materials	Child explores the properties of materials and uses their understanding of them to achieve design goals.
CD2: Use materials creatively	Child uses materials in creative ways.
CD3: Trialling	Child is confidence using a ‘trial and error’ approach and they show or talk about why some things do or don't work.
CD4: Workaround	Child uses previous experience and knowledge to develop practical workarounds.
CD5: Adjusting goals	Child adjusts their goals based on feedback and evidence.
CD6: Suggesting improvements	Child makes suggestions as to how the artefact could be improved.
S: Social learning	

S1: Listening	Child listens to the ideas of others.
S2: Building on ideas	Child builds on the ideas of others.
S3: Supporting	Child supports the learning of other children.
S4: Effective collaboration	Child collaborates effectively with other children.
S5: Seek assistance	Child seeks ideas, assistance and expertise from others.
S6: Feed back	Child gives feedback on the outputs of others, if asked to do so.

Appendix 3: Early Coding Skills and Knowledge Framework (Scott, 2019)

Coding skill or knowledge	**Definition**
ECSK1: Directional language	Child uses directional language (left, right, backwards, forwards, up, down).
ECSK2: Counting	Child counts using ordinals (first, second, third).
ECSK3: One-one correspondence	Child understands one-one correspondence.
ECSK4: Identifies patterns	Child can identify patterns.
ECSK5: Sequencing	Child can create/ re-create a sequence.
ECSK6: Directions	Child is able to give and follow directions.
ECSK7: Cause and effect	Child understands cause and effect (if… then…)
ECSK8: Defines algorithms	Child defines a list of steps (algorithm) to complete a task
ECSK9: Decomposes	Child decomposes (breaks down) the steps needed to solve a problem into a precise sequence of instructions.
ECSK10: De-bugs	Child identifies and addresses bugs or errors in sequenced instructions (de-bugging).
ECSK11: Identifies loops	Child identifies repeated patterns in code that could be replaced with a loop.