Humanoid Educational Service Robots in Primary Classrooms: Design-based Strategies for Pre-implementation Planning

by

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma, except where due reference is made. To the best of my knowledge, this thesis contains no material previously published or written by another person except where due reference is made in the text of the thesis.

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Abstract

Educational technologies are frequently implemented without much pedagogical planning, and teachers are then asked to match technological affordances with learning 'tasks' in piecemeal and ad hoc ways after the most important evaluation and adoption decisions have already been made. This thesis takes a design-based research (DBR) approach to this problem using a case study to develop pre-implementation strategies to plan for the introduction of an educational service robot into a primary school classroom.

The design process included establishing requirements based on teachers' knowledge of relevant technology, pedagogy and content (the TPACK framework). A prototype learning activity was designed and iterated to test alignment to the TPACK framework and to retire risks over the course of the project's stages. The DBR approach was able to evaluate degrees of fit between the robot's affordances and the teachers' level of technological expertise, their pedagogical knowledge and the current curricular context. It was proposed that design guidelines derived from this process would enable teachers and other education specialists to plan for the meaningful introduction of the educational service robot into their classrooms.

It was shown that the robot's most sophisticated feature—its purported capacity for naturalistic conversation in educational settings—did not align well with the teachers' technological expertise, ruling out its potential for flexible and rigorous language teaching at this stage of its development. However, it was seen to be within the scope of the teachers' knowledge to use the robot to introduce programming skills to 6-10 year old students in an engaging, 'tangible' way, thus addressing a growing curricular demand. This study showed that by using design based research, an educational technology implementation team could plan for the use of the robot in line with emerging computational practice pedagogies with primary school students of different ages and with different degrees of technological experience.

Publications Arising from This Thesis

The following publications have been derived from this research.

- Naznin, K., Farrell, V., von Baggo, K., and Woodward, C. "Simon Says "Use of Humanoid Robot to Teach Kids" – A Case Study of Expectations and Reality", 10th International Conference on Interfaces and Human Computer Interaction, 2 – 4 July 2016, Funchal, Madeira, Portugal.
- Naznin, K., Farrell, V., von Baggo, K., and Woodward, C. "Technology in the classroom: A pilot test with a humanoid robot", 10th International Conference on Interfaces and Human Computer Interaction, 2 – 4 July 2016, Funchal, Madeira, Portugal.
- Naznin, K., Farrell, V., and von Baggo, K. "Designing for Technology Enabled Constructivism Learning", 10th International Conference on Interfaces and Human Computer Interaction, 2 – 4 July 2016, Funchal, Madeira, Portugal.

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1 Introduction

This study had two early aims—to explore the potential use of a humanoid educational service robot in primary schools in a local context and to see what this would mean for implementation of this kind of education technology more generally. Humanoid robots have been introduced into classrooms in a range of isolated studies during the past decade (Kanda, Shimada & Koizumi, 2012; Wei et al., 2011; Blar et al., 2014; Magyar et al., 2014; Keane et al., 2016). However, extensive use of this technology seems, at this point, to be still some way off, partly owing to its expense. However, this thesis makes timely suggestions about improving the kind of pre-implementation design that will be necessary in planning for its eventual implementation. Classroom settings are very complex, and implementation design for the use of educational service robots will need to take into account all this complexity (Reich-Stiebert and Eyssel, 2016; Fenstermacher, 1994; Mishra & Koehler, 2006). Working out how to factor some of this complexity into the *pre*-implementation design process seems, therefore, a useful endeavor at this point.

One way of factoring complexity into the design is by drawing on teachers' knowledge. Current design based research methodologies do this in various ways, but this thesis proposes the use of the TPACK framework, which provides a way of capturing and synthesising teachers' knowledge of educational technology, relevant pedagogy and curricular content (Mishra & Koehler, 2006). Making sure these elements are aligned with the proposed education technology intervention means involving teachers in implementation design teams where they can work with education technology researchers, technologists and other implementation specialists on specific interventions. This is not standard practice in implementation design for primary schools; however this study aimed to lay some groundwork that might encourage this kind of future collaboration.

Working collaboratively with technology developers also allows researchers to draw on and integrate best practice in the management of technology design and development projects (McKenney & Reeve, 2013). This project planned to use design based research (DBR) methodologies as the basis for defining and managing the research (Brown, 1992; McKenney & Reeve, 2013), as DBR can help reduce gaps between technologies and end users in education contexts. However, the researcher also planned to draw on the methods that are brought to the design table by research into human-computer interaction and human-robotics interaction, especially in terms of gathering user input, creating prototype designs and testing with users.

DBR emphasises the need to ground education research in a local context. In this study, the work was conducted in Melbourne, Australia, which is an affluent country with a recently introduced national curriculum policy for ICT learning in primary schools. Six primary school teachers from four schools participated in the research as co-designers, developing the initial design requirements for the evaluation of the robot's potential use in their classrooms.

Finally, this project sought to contribute to the growing body of knowledge about what kinds of learning could take place as a result of implementing more widespread use of humanoid robots in school settings. As Reich-Stiebert & Eyssel (2016) note, “It is critical that research on educational robots does not simply boil down the development of a tool that supports teaching and learning, but that such research also opens up novel perspectives on how to make use of the potential of education robots most optimally" (p.679). The researcher had access to a recently manufactured humanoid education service robot (the 'NAO' robot produced by Softbank Robotics), so the project was envisaged with the evaluation of this particular robot in mind.

Based on the teachers' input, a learning activity was developed (in two iteration cycles) for the purpose of evaluating this robot's capacity to enhance learning in the local classroom context. Evaluating the robot in terms of what it could contribute to learning meant trialing it with students, so the project was designed to include testing in a user laboratory and, if there was time, in classrooms. Thirty-seven primary school students participated in this stage of the project. 'Learning' is not in any sense an unencumbered construct, however, and the project needed to take into account relevant learning theories, as well as recent research into technology-related curricula, including recommendations for computing curricula by major professional computing societies (ACM/IEEE-CS Joint Task Force, 2012). The results and analysis from this evaluation process are presented and discussed in Chapters 6 and 7 of thesis.

1.1 The significance of the research

The significance of this thesis can be viewed from two perspectives. Firstly, because humanoid robots are still unfamiliar in many schools, research into their potential implementation could be used to advise research leaders in schools and governments on future paths they could take to evaluate the capabilities of robots on the market and to plan for their effective implementation in schools.

Secondly, there is a pressing need to involve teachers directly into the design process for better implementation of technology in schools (Schmidt et al., 2009). This thesis demonstrates one way of undertaking participatory design in pre-implementation planning for an educational technology.

1.2 Overall aim and main research questions

The aim of the thesis was to evaluate the potential of the humanoid education service robot and develop pre-implementation strategies to plan for its introduction. This meant designing a learning activity that would help to evaluate its capability by aligning its affordances with the right curriculum and pedagogies. In addition, it was hoped that the study would identify principles and guidelines that could be used by others looking to create similar learning environments with similar robotic technology.

Following a review of the literature on educational technologies, available technology tools in classrooms, learning theories and how to best evaluate teachers' preparedness to use robots in schools, the following research question was posed:

How can education technology implementation design be optimised for the introduction of humanoid educational service robots in the classroom?

Sub-questions relating to the topic were:

- *How can teachers' knowledge be incorporated into planning processes to optimise the implementation design for the introduction of a humanoid service robot into a primary school classroom?*
- *How can the potential of the humanoid educational service robot be evaluated using design principles?*
- *What factors need to be addressed in the pre-implementation evaluation process?*

1.3 Thesis structure

This thesis contains seven chapters. This chapter outlines the context, significance and goals of this research.

Chapter 2 - Literature review provides a review of research into educational technologies, technology tools used in classrooms, relevant learning theories and teachers' preparedness to use robots in schools. The review indicates that humanoid robots have the potential to enable constructivist learning among children. The review also identifies gaps in the research in terms of the gulf between education technology implementation design and its eventual end users, both teachers and students. It concludes that design based research (DBR) could offer a fruitful method for bridging this gulf and that, in addition, teachers should be brought into the design process using the TPACK framework.

Chapter 3 – Research Methodology outlines DBR methodology, including its four steps, and explains the significance of this methodology for the thesis. DBR is contrasted with other related methodologies. The chapter discusses the steps of DBR, and other principles for implementation design. The TPACK framework is also further discussed and proposed as a theoretical framework for capturing teachers' knowledge and organising it as part of the design input. The plan for the whole study is presented, based on the following DBR steps: identifying problems, analysis of practical problems, constructing design specifications, constructing a learning prototype and testing the prototype following iteration cycles.

Chapter 4 - Teachers' input demonstrates how the project involved teachers as co-designers in the design process. The relevant teachers shared their experience, understanding and expectations related to the potential use of the humanoid robot in the classroom. These contributions were thematically analysed and classified in terms of the TPACK framework. A set of design guidelines was developed as a result of this process, and is presented at the end of the chapter.

Chapter 5 – First iteration of the evaluation prototype proposes a skeleton design and implementation of a learning activity as a prototype for evaluation of the robot based the teachers' input in Chapter 4. Collaboration with technology developers detected implementation risks related to the use of this robot for teaching language skills. These risks are discussed in the chapter, the rational for redesigning the learning activity is given and the second iteration is prefigured.

Chapter 6 – Iteration 2: Using the robot to teach programming proposes a second learning activity that could minimise the technological risks associated with the first prototype design. This involved returning to the teachers' input, as well as a further review of the literature on using robots to help children learn computational thinking. The chapter then reports on the testing of the second learning activity and discusses what this kind of evaluation can contribute to implementation planning.

Chapter 7 – Discussion and conclusion elaborates on the implications of the findings from Chapters 4, 5 and 6 and discusses how these could provide support for educational technology implementation design. It also discusses the contribution made by this research to the fields of education technology implementation and the use of robotics in education in terms of a 'blueprint' for alignment. The conclusion provides a summary of the thesis and touches on potential future work aimed at extending the alignment framework.

The Appendix contains documentation indicating ethics approval to conduct interviews with teachers (SUHREC Project 2014/154) and to conduct an observational study with children (SUHREC Project 2015/300) which was granted for the work described in Chapters 4 and 6. It also contains documents and data pertaining to these two studies.

2 Literature review

2.1 Introduction

Much technology has been introduced into classrooms in the past two decades and computational technology is "well entrenched in the daily lives of all ages within Australian society" (Marc, 2001, p.35; Campbell, 2009). Present-day educators aim to exploit these technological advances to create engaging and effective learning environments. Robots have become a focus they offer an engaging means to combine science, engineering, technology and mathematics (STEM) pedagogies (Mataric, Koenig & Feil-Seifer, 2007). Robotics technology has the potential to enable curriculum requirements to be met while offering a novelty factor and opportunities for social interaction.

While many relatively new technologies were considered for this project, e.g. interactive whiteboards, digital tablets, multi-touch tables, augmented reality, and various robots, including Robovie, the Sony AIBO and Lego Mindstorm, a 'NAO' humanoid education service robot was selected as it was an unfamiliar technology in this research context and was yet to be used in more than a handful of classrooms. This presented an opportunity to research the implementation of a technology that was unfamiliar to both teachers and students.

Several factors need to be considered when offering a new technology to a school because of the complexity of the classroom context and the reliance on both human and technical resources. Before any unfamiliar technology can be used in the classroom, it is necessary to consider how it will be implemented within a school context. Teachers rely on their broad knowledge of teaching and learning theories and methods, as well as on their technical expertise, in order to use any technology tool in a learning environment. Relevant learning theories and their implications for technology-based instructional design are presented below. Learning with robots draws on constructivist learning theory, which emphasises exploratory, student-centred approaches (Papert, 1991).

This thesis asks: What is the best way to plan for the introduction of robots? Can we learn from the ways other technologies have been implemented in classrooms? Various technologies have been introduced with mixed success and much has been learnt in recent years about ways to implement education technologies better. In particular, design-based research offers a way to plan for and to implement design solutions in educational contexts, and one way of considering education technology implementation is to look at it as a design problem. This thesis shows that, by using participatory design principles, researchers and educational technologists can work with teachers and use their complex classroom knowledge as inputs into the design process. Thus the main research question was: *How can education technology implementation design be optimised for the introduction of humanoid educational service robots in the classroom?*

Much research has focused on teachers as a 'problem' in the introduction of technology to classrooms, especially in terms of their ‘lack of acceptance’ of emerging technology and ‘lack of technological fluency’ (Bers et al., 2002). However, teachers’ knowledge has more recently been recognised as a key resource and many studies instead are focusing on how participatory design can draw on teachers’ knowledge. Teachers’ knowledge about technology implementation can be classified and evaluated in terms of the technological pedagogical content knowledge (TPACK) framework (Mishra & Koehler, 2008). In order to understand what is required and to begin planning for the introduction of a humanoid education service robot into a primary school classroom, this chapter will review research into both design-based research methodology and the TPACK framework. Before this, it provides relevant background information on educational technologies (including the use of robots in education), associated learning theories, related educational technology tools and suitable approaches for technology implementation design.

2.2 Educational technologies

Various forms of technology have been introduced into Australian classrooms recently under the assumption that all students are ‘digital natives’—a so-called 'D-generation' who has grown up in a world where digital technology is a given (Marc, 2001; Jukes & Dosaj, 2006; Campbell, 2009). Commentators have claimed that the internet, wireless technology and mobile phones, and multi-touch devices make it possible for individuals to learn, alone or with anyone, at any time and in any place (Simon, 2012). Mobile technologies and computers are tools that many children have used from a very young age and children are often considered to be more comfortable with them than their parents and teachers (Campbell, 2009). In this context, schools have increasingly been urged to emphasise digital literacy and much research has been undertaken in support of this goal. Concern has been raised that traditional education is not capable of “preparing learners to be productive in the workplaces of today’s society” (Yelland, 2001; Clarke & Zagarell, 2012). The notion has gradually emerged that education and digital technology and its applications should be merged and studies have sought to determine how educators can achieve the knowledge, skills, and experience needed to select, use, integrate, and evaluate technology suitable for the purpose of educating young children (Fischer, 2009; Simon, 2012).

However, the role of technology in early childhood education (especially for 5- to 8-year-olds) remains a controversial topic (Mouza, 2005). Critics of its use argue that “virtual reality technology may replace essential learning experiences for children … [and] experiences such as play and experimentation with real objects” (Cordes & Miller, 2000; Healy, 1998; Mouza, 2005). Mouza has also claimed that the use of virtual reality technology may “prevent children from interacting with peers and other adults”, potentially resulting in “social isolation” and that computational technology can create health problems such as “repetitive stress injuries, eyestrain, obesity, and occasionally, some physical, emotional, or intellectual developmental damage” (Mouza, 2005, p. 515). Research on early childhood development suggests that “young children need opportunities to learn by doing through interacting, exploring, and manipulating real world objects” (Bransford, Brown, & Cocking, 2000; Piaget, 1972). Reports on early childhood education by the Australian Federal Government have highlighted the integration of ICT–enhanced learning for young children, while bringing to the fore “resistance from practitioners who value more concrete activities” (Turnbill, 2001).

In 2000, The American Academy of Paediatrics (AAP) issued a formal statement about children, adolescents, and television that included findings about television use in early childhood. Many of those findings suggested that screen time is detrimental to young children (Clements & Sarama, 2003). However, in October 2011, the AAP updated their position and made it clear that their earlier report was intended to provide guidance about passive television viewing, not interactive technology use. The important distinction in the new AAP report was that all screen time is not equal for children, especially when it comes to preschool classrooms. It is clear that we do need more research as to whether technology implementation in preschool programs can be detrimental or developmentally appropriate. Research summarised by Clements & Sarama (2003) has suggested that it can be beneficial if the teachers are well trained.

Though governments allocate millions of dollars for technology in schools, some studies have argued that technology in education confers either a weak positive effect or an insignificant effect on average student learning achievement (Mouza, 2005). On the other hand, many studies suggest that technology can indeed be beneficial when properly integrated and that it will not diminish the benefits associated with more traditional learning (Clements, Nastasi, &

Swaminathan, 1993; Mouza, 2005). Indeed, according to Clements, Nastasi, and Swaminathan (1993), ‘‘compared to more traditional activities, such as puzzles assembly or block building, the computer elicits more social interaction and different types of interaction”(Clements, Nastasi, & Swaminathan 1993, p. 60 cited in Mouza, 2005, p. 515). Computers can serve as facilitators of social interactions. Clements and Sarama report on a study showing that “Children spent nine times as much time talking to peers while on computers than while doing puzzles” (2002, p. 341). In another study, “Computer activity was found to be more effective than toys in simulating vocalisation in preschool environment and evoked higher levels of social play” (McCormick, 1987). Finally, it has been argued that technology “can also contribute to the social interaction of children with disabilities” (Clements & Sarama, 2002). According to Clements and Sarama (2002), “research on young children and technology shows that we no longer need to ask whether the use of technology is developmentally appropriate” (p.340).

Teachers and students use digital technology for a wide variety of tasks in their lives. Therefore, the main focus of recent research has been on the impact of technology in education and to provide suggestions to teachers or educators about ways of using technology that minimize risks and lead to better educational outcomes. For example, the 100 Days of School project (Mouza et.al, 2005) considered “whether physical concerns can be addressed by monitoring the amount and ways in which children work at the computer” (p.587).

Research on children’s development suggests that very young children “need opportunities to learn by doing through interacting, exploring, and manipulating real world objects” (Mouza, 2005, p.587). Very young children are often able to use software for exploration and self-guided instruction (Clements & Sarama, 2002). Using digital technology in early education can support children’s development by creating environments where students can learn by doing, by helping students graphically visualise concepts (Bransford et al., 2000) and by augmenting and reinforcing traditional learning (Mouza et.al, 2005, p.587). And as noted, computers can also serve as facilitators of social interactions and lead to greatly increased levels of discussion between children (Clements & Sarama, 2002).

There are many factors that need to be considered for the effective integration of any technology tools into classroom practices. Carrasco & Torrecilla (2012) determined that using a computer at home and school had a positive effect on the achievements schoolchildren in sixth grade and argued that access to educational technology, and its use by students and teachers had positively affected teaching and learning (Carrasco & Torrecilla, 2012, p.1125).

Another study in New South Wales, Australia also suggested that access to technological resources is a factor and that new technologies needs to be thoughtfully integrated with traditional resources (Hayes, 2007).

2.3 Robots in education

During the 1970s, early childhood educators, universities, and developers started to experiment with robotic technology in the classroom, and several computer-based applications were developed for children (Simon, 2012). Robots have been a particular focus as they have the potential to enhance learning in terms of physical, social and cognitive skills. Recent research into how children can learn with robots draws on constructionist theories of learning (summarised in Flannery & Bers, 2015).

Before going into the potential offered by robots in education, relevant learning theories are described below along with their implications for digital technology based instructional design

2.3.1 Behaviourism

Behaviourism does not consider what is happening inside the learner. Instead, it implicitly suggests that learners participate passively in learning contexts and have motivational responses. "Knowledge is seen as objective, given and absolute" (Semple, 2000, p.22; Sang et al., 2000).

According to Skinner, there are four important behavioural aspects to learning (summarised in Semple, 2000, p.22; Skinner, 1953):

1) Steps in the learning process need to incrementally build on previously learned behaviour.
2) As the learner's behaviour is systematically reinforced in the learning environment, so learning needs to be rewarded regularly, at least in the early stages.
3) Feedback should be given immediately.
4) The learner should be given 'discriminative stimuli' that point them in potentially profitable directions.

These notions seem initially compatible with computer based learning. Using the principles of 'drill-and-practice' tutorial programs can give 'packets of information' to users to respond to and follow up regularly with appropriately targeted feedback (Semple, 2000, p.22; Bradley & Boyle, 2004). Learners can practise simple activities in this way before they engage in complex activities in a "precise procedural model of linear or branching programs" (Sang et al., 2000).

Such programs may seem to be ‘interactive’ rather than ‘reactive’. However, if the user follows the same path repeatedly, they will get the same response every time, which may diminish their sense of control over the learning process (Hayes, 2007).

2.3.2 Cognitivism

Behaviourist theory attempts to provide an account of learning that is grounded in observed behaviour rather than internal cognitive processes. According to cognitivist theories however, learning is grounded in the process by which learners actively generate symbolic mental associations (Semple, 2000, 23).

Technologies based on cognitive learning theories aim to “[amplify] human abilities such as memory and processing” (Semple, 2000, 23). Computer-based tools like the graphic organiser ‘Inspiration’ attempt to support “more sophisticated use of techniques such as linear chains, flow charts and hierarchy maps” (Campbell, 2009).

Taylor called this type of computer based technology 'inauthentic' labour’ (Taylor, 1980; cited in Semple, 2000, p.23); however, Jonassen argued that “children cannot use these tools without thinking deeply about the content that they are learning” (Johanssen, 1994; cited in Semple, 2000, p.23). In cognitive theories of learning, learning ‘tools’ set the direction and guide and support cognitive processes, meaning that the locus of control is beginning to lie more with the user, rather than with the designer and the computer program.

2.3.3 Constructivism

Constructivism takes this ‘turn’ in learning theory even further by characterising the development of knowledge as a process by which learners play a much more active role in constructing their own understanding (Phillips, 1995; Steffe & Gale, 1995). According to Glasersfeld, “knowledge is the search for fitting ways of behaving and thinking” (cited in Smith, 1999, p. 152). Similarly for Smith, “Constructive operations are not operations in the mind, but are operations carried out mentally” (Smith, 1999, p.154).

Smith also notes the following key principles of constructivism (cited verbatim, p.159):

1) *Construction is undertaken by learners, not teachers.*
2) *The learner’s construction makes use of available beliefs and expectations in grappling with new ones.*
3) *Teaching can provide the opportunity for, not a guarantee of, the transmission of knowledge.*

4) *Construction always involves socio-cultural construction*.

Constructivism is defined by its view that knowledge is internal to the learner and a learner's understanding is an interpretation of the external world (Jonassen, 1991b; Vrasidas, 2000).

Constructivist teaching theories are related to the concept of monitor learners (Francis-Baldesari & Pope, 2008; Danielowich & McCarthy, 2013) who are supported to adopt doable models, thus enabling them to think and act like experts (Jordi, 2011). This approach is based on the belief that the role of education should be to create an environment where learners have the opportunity to control their own learning (Vrasidas, 2000; Dames, 2013).

According to Piaget (1970), "children construct their own knowledge through their experiences in accordance with their cognitive development". In this sense constructivism emphasises personal exploration and expression. The teacher can organise and support "appropriate learning environments according to the child's cognitive state" (Gomes et al., 2012; Phillips, 1995).

The constructivist paradigm has been influential in science and mathematics education; however there has been less work which focuses on constructivism in the area of computer science education (Ben-Ari, 2001). In this context, a constructivist would claim that each student creates their own individual mental model in learning about computers, both in terms of understanding hardware and software. Computer science education takes into account artefacts including programming languages and applications which necessitate highly elaborated models on the part of learners. As with other scientific fields, they need to construct a similar but not identical model representing their ontological constructs. Ben-Ari (2001) uses the example of mental models underlying the understanding of a word-processor to illustrate this. When using the word processor as a technological device, it is often not possible to argue that a mental model is incorrect; however in learning to code, the computer provides its own ontological reality and the learner has to come to terms with this as a given. Ben-Ari (2001) argues that this makes computational learning somewhat different from that of science or mathematics. This difference plays out in relation to the kinds of computational learning described later in this thesis, especially in the kinds of common coding practice that relate to 'debugging' and 'tinkering', where learners' mental models are often in flux.

Under constructivist theory, the characteristics of children themselves influence their learning (Thambusamy & Elier, 2013). These characteristics can include "their cultural and socio-economic background, their values and beliefs, and their motivation and expectations of the learning environment" (Wei et al., 2011).

One offshoot of constructivism is constructionism, which was conceived by Seymour Papert, a student of Piaget. Constructionist learning theory posits that student-centred learning is enabled when “students are encouraged to work with tangible objects in the real world and use what they already know to gain more knowledge” (Papert, 1991). As with constructivism, students are engaged in the discovery based endeavour of ‘constructing’ their own learning, and teachers act as facilitators rather than instructors (Papert, 1991).

In light of the above discussion, constructionist learning theories with their implications for emerging technology provide the best theoretical support for this project. The use of emerging technology (and robotics technology in particular) is highly compatible with constructionist learning theory and associated pedagogies. Many education technologies allow teachers to develop lesson plans around activities that enable constructivist or constructionist learning.

In recent years, researchers have also emphasised the importance of ‘joyful’ learning for children (Fisher, 1998; Heywood, 2005). Based on this notion, technology has been used to develop so-called Joyful Classroom Learning Systems (JCLSs) to support children’s learning in various ways (Wei et al., 2011). The notion of robots as engaging learning companions arose from these developments and the LEGO Mindstorm platform, WowWee’s Robosapien, and the Aldebaran robot NAO (which is the object of this research project) are all examples of ‘fun’ robot learning companions that children can touch and operate (Wei et al., 2011).

The most important developments in educational robotics began with LOGO. The LOGO programming language was invented in 1967 by Papert, who first introduced the notion that children might learn programming concepts in the classroom. Papert proposed that children could also learn mathematics through programming (Papert, 1991). LOGO thrived and became the foundation of LEGO’s robotics products, but these soon became lost within a sea of commercially developed preschool software. Toy companies were keen to cash in on the newly available computers in the last decade of the twentieth century, but they demonstrated little understanding of or interest in how young children learn (Simon, 2012).

More recently the robot dog AIBO, the NAO robot, Robovie, and the Joyful Classroom Learning System have all contributed to children’s social and educational relationships with robots (Shamsuddin et al., 2012; Hsien & Chun-Chia, 2012). These robots are all used with young children in classroom situations and various success stories have been reported (Cabibihan et al., 2013).

The relevant Human-Robot Interaction (HRI) literature is now reviewed for its implications in education and to discuss how robots can support the creation of a constructionist learning environment. Other learning theories are also mentioned when relevant.

2.3.4 The Sony AIBO

The Sony AIBO (Artificial Intelligence Robot) entertainment robot dog (which sold for about $1500) could learn new behaviours from the way humans interacted with it and it could also autonomously seek out and kick or handle a ball (Kahn et al., 2012). In one instance the AIBO robot was used in elementary school classrooms as a simple storybook reader. At the beginning of this project, the robot's task was to read stories to children, but this did not work in a noisy classroom because the robot's microphone and speaker were inadequate to the task (Decuir et al., 2004). To solve this issue, researchers next developed an AIBO program to "enable the robot to listen to its environment and try to localise the sound of a human voice" (Decuir et al., 2004). Examples were given of reading comprehension radically improving when the AIBO robot was used (Decuir et al., 2004).

2.3.5 The humanoid robot, Robovie

Robovie, a humanoid robot that was marketed as a teaching assistant, was used in various studies (Kanda, Shimada, & Koizumi, 2012). In one, Robovie was responsible for managing a class of sixth graders (Kanda et al., 2012). Its task was to explain the use of Lego Mindstorm and perform some basic management of class behaviour. The results from this activity showed that social behaviours exhibited by Robovie encouraged children to work more for the first two lessons even though they had less effect in later lessons (Kanda et al., 2012).

Robots have also been used successfully to teach language skills. Again, incorporating social behaviours has been found to be effective in such cases (Kanda et al., 2012). Robovie has been used in museums for interactive sessions with children based on social and cultural relationships (Kahn et al., 2012). During these sessions many children were observed to develop significant and meaningful relationships with the humanoid robots.

Children have increasingly grown up with humanoid robots and questions have arisen about the extent to which children they potentially form social relationships with them. These questions are puzzling because on the one hand these robots are artefacts that humans have created. In this sense, they are just tools, like a broom that you use when you want then stick in a closet when you are done. On the other hand, these robots are acting and speaking in ways that represent canonical behaviours of an autonomous, thinking, feeling, social, and moral human being. In this sense, they could be viewed as offering the same social affordances as a human thus meriting the same moral considerations.

One study that investigated this issue focused on the interactions between children and the Robovie robot (Kanda, Shimada, & Koizumi, 2012). Robovie demonstrated a coral reef aquarium, provided some explanation about some of the corals and began a game of “I Spy,” which involved thinking of an object in sight in the room and giving the other persons clues to see if they could guess the object. The session ran for fifty minutes and focused on whether children thought of Robovie as a social being.

The results from this study suggest that eventually children could develop social relationships with humanoid robots. The researchers found that a large majority of children engaged with the robot in ways that could be described as ‘social’. In terms of their physical and verbal behaviour, 97% of the children shook hands with Robovie, 100% of the children pointed to the coral after Robovie asked the child to do so, and 94% of the children hugged Robovie after Robovie asked politely if it could give the child a hug. Children also conversed with Robovie, sometimes deeply. More importantly, the study also showed that the majority of children thought that Robovie had mental states and feelings and that Robovie was intelligent. They conceived of Robovie as a ‘social other’ who was trustworthy and empathetic. Three quarters of the children believed that “Robovie could be their friend” (Kanda, Shimada, & Koizumi, 2012, p.31).

2.3.6 Lego Mindstorm

Lego Mindstorm is a physical robotics system with virtual software that controls the robot. Kanda, Shimada & Koizumi also investigated Lego Mindstorm in the study described above where they compared its use in the classroom with that of Robovie (Kanda, Shimada, & Koizumi, 2012). The researchers worked with teachers who wanted their students to gain basic knowledge about using Lego Mindstorm, such as how to run and program the motors and the touch sensors. The teachers also wanted the students to apply this knowledge to a concrete problem. They designed a Lego Mindstorm sequence, in which children learned with Robovie for seven lessons.

The results from Kanda, Shimada & Koizumi’s project had useful implications for future design. Firstly, in their learning sequences, the robot's role was that of facilitator rather than instructor or learning companion. This built on the tenets of constructivist learning mentioned earlier which stipulate that the role of a teachers is more properly envisaged as that of facilitator rather than instructor, since students construct their own knowledge by learning from doing. This extension of the concept of 'teacher as facilitator' to that of 'robot as facilitator' (in the context of a student centred learning environment) was explored in this thesis.

Secondly, Kanda, Shimada & Koizumi's study showed that children's learning and social behaviour were entwined in terms of how they were affected by interaction with the humanoid robots. This second contribution embodies the constructivist assumption that learning needs to be seen in its social context since "construction always involves socio-cultural construction" (Smith, 1999). In examining how the robot could encourage children to interact in the classroom, Kanda, Shimada & Koizumi showed that its ability to provide learning experiences based on social interaction could be the humanoid robot's most useful affordance. The use of humanoid robots in the classroom and their relevance to this research is discussed next.

2.3.7 The NAO humanoid education service robot

Recently there has been an increase in research into the increasingly prevalent use of social robots with children in educational settings (Kennedy et al, 2016). Several researchers have applied well-established techniques to the educational domain, and they have used different technologies to develop and evaluate so-called social robots (Timms, 2016). Timms (2016) claims that over the next 25 years, robots will appear in many aspects of our lives and they seem unavoidable in the education sector where there is a clear role for them as helpers. Most of the work conducted within the field of Human-Robot Interaction (HRI) is motivated by previous success stories from over a long period so that this field of research is now sustained by its increasing real-world application.

Studies have established that "robots can be used to successfully teach children, and also offer unique learning experiences. For example children can teach a less able peer (in the form of a robot), which may not otherwise have been possible" (Kennedy et al, 2016; Hood et al, 201; Tanaka & Matsuzoe, 2012). This technology has an impact on the classroom, in terms of both child and teacher behaviour.

The humanoid NAO robot was designed for educational purposes. It uses a cloud based web application based on the Google App Engine, which is part of the Google Cloud Platform (Magyar et al., 2014). In teaching applications, International Development Markup Language (IDML) tools are used. As an example this technology has been used to motivate learners who have been hospitalised by creating a robot companion for them (Magyar et al., 2014).In human-robot interaction, emotional expression is a key area of research (Magyar et al., 2014). If a user receives a positive answer from the robot with an emotional expression, it can be more motivating than just getting a simple 'correct' or 'incorrect' answer. Using a humanoid robotic platform, the learning process can be more natural. The robots are marketed as being easily customisable (Magyar et al., 2014). They can walk, talk, listen, and interact with the environment in a range of ways. So education technology researchers have been interested in the possibility that teachers could use them for multiple purposes (Magyar et al., 2014).

LEGO Mindstorm, WowWee's Robosapien, and Aldebaran Robotics' NAO are all examples of robot learning companions. The NAO Robot too has been used in the classroom as a learning companion to support children's learning in mathematics and other subject areas. The NAO robot is able to engage students in a classroom through emotional expressions, natural interactions, and entertainment. Because they can be customised, teachers can use NAO robots for multiple purposes, as a model learner for instance or as a teacher's assistant.

Timms (2016) notes that "There is evidence from neuroscience that human acceptance of technology is influenced by how human-like it appears" (p.705). Krach et al. (2008) used "functional magnetic resonance imaging (FMRI) to study the brain activity of participants, who played a game using four different types of components: a computer, a functional robot, a humanlike robot and a human" (Cited in Timms, 2016, p.705). The participants in this study played randomly using different devices. The results of this study identified that "participants showed activation in the areas of the brain associated with 'theory of mind' (i.e., attribution of human intention) in an order of increasing human-like features (computer < functional robot < human-like robot <human)" (Timms, 2016, p.705). Other researchers have questioned these conclusions, calling for further investigation into relationships between the appearance robot and learners' attention to them and acceptance of them as indicated by their brain activity (Chaminade et al., 2012; Krach et al., 2008).

So it seems that integrating more human-like features into robots destined for the classroom would improve their acceptance by teachers and learners. In general, the common assumption is that a humanoid robot should be designed to be as much like a human as possible, and if a robot is made with the same physical attributes a human has, then based on current advances in robotics technology it will be able to do what a human can do within the next 25 years (Timms, 2016). However, the reality is that doing any simple activity like a human is still challenging for robots. For example, recognising objects in the environment, picking up objects and manipulating them are all very difficult tasks for robots (Timms, 2016).

A notable advantage of producing humanoid robots is that a humans can easily interact with them. This is important in the classroom environment for teachers and for students. As a human, we do not need to learn to control a human type robot, while we do need to learn how to control non-humanoid robots like the AIBO, and robotic floor cleaners (Timms, 2016). Several interfaces are offered nowadays for performing different tasks, and sometimes it is not easy to learn various technologies. Over the coming quarter century, more robots will appear in our daily lives, assisting us in a range of tasks. If there is no standardisation of interfaces then it will be difficult for a human to learn how to operate many different kinds of robots (Timms, 2016). To minimise this risk, the obvious way to standardise them is to make them humanoid (Timms, 2016). We as humans are very used to working with other humans; therefore to 'work with' a humanoid robot, we would not need to learn anything new.

So humanoid robots could be useful in the classroom. The robot could support a practitioner by following his/her instructions as to what to do. For instance a teacher may notice that a group of students in the classroom is having issues setting up an experiment. The teacher may be busy helping another group, and so they could ask the robot to go and help the group and observe whether they set things up correctly and keep on track. In this case the learners too would tend to respond more naturally to a humanoid robot teacher.

The available emerging technology tools for education that enable constructivist learning are described in the next section.

2.4 Technology implementation

What is the best way to introduce robots? Can we learn from the ways other technologies have been implemented in classrooms? This section discusses various educational interactive technology tools that are currently used in primary school education and issues that arose in their implementation, providing information which could be pivotal to this research, especially in the implementation stage.

2.4.1 Screen-based technologies

Passive and screen based

The electronic television, invented in 1927 by Philo Taylor Farnsworth, can be considered a passive screen-based technology. Television offers a passive learning experience, compared to video games and computer screens, which can be seen as supporting active and interactive use. As noted above, there has been much debate over the extent to which passive screen technology could benefit or disadvantage pre-school age children (Linebarger & Walker, 2005; Simon, 2012, p.35).

Interactive and screen based

According to psychologists, interactivity can be associated with “motivation, interest and persistence” and learning can be enhanced “when students are actively engaged on a task rather than cast as passive recipients” (Atkins, 1993, P. 333). Interactive technology enables a more child-centred, play-oriented and diverse classroom. According to Ishii (2008), tangible technologies are important for learning especially if they use natural interfaces that require “little cognitive effort for the learner” (Guo & Sharlin, 2008; Starcic & Zajc, 2011; Poupyrev, Nashida, & Okabe, 2007). With natural interfaces, children can focus on the content because they do not need to learn how to operate the technology using a mouse and/or keyboard. As Simon states, “Children are natural ‘manipulators’ of the world. They learn through controlling the movement and interactions between objects in their world - dolls, blocks, toy cars, their own bodies” (Simon 2012, p.38). Tangible User Interfaces (TUIs) can offer various kinds of interactions as this technology enables user to solve issues “with concrete physical objects and physical action” (Starcic & Zajc, 2011; Poupyrev, Nashida, & Okabe, 2007). While playing games, TUIs offer children two environments at once through the connection of virtual and physical interfaces (Starcic & Zajc, 2011).

Interactive whiteboards

An interactive whiteboard is a large interactive display in the form of a traditional whiteboard, which has a touch screen functionality and is suitable to use in the classroom. The first interactive whiteboard was developed by PARC around 1990 for office use and after that it started to be used in kindergartens and primary school classrooms. It is a digital screen based technology which has been used widely in K-12 education. Early studies seemed to indicate that interactive whiteboards represented a promising direction in technology that could enable learner-centred pedagogies; they have become an increasingly common tool and much research has focused on how they could be used more effectively. However recent studies have also questioned the extent to which they do support the promised level of interactivity (Simon, 2012). Although many studies cite positive effects on students’ learning, studies based on collaborations with teachers have questioned whether they are inherently able to mitigate passive learning and also whether they represent value for money in cash-strapped schools (Smith, Higgins, Wall, & Miller, 2005; Simon, 2012).

Tangible tabletops

Tangible tabletop systems are examples of TUIS. After interactive whiteboards, tabletop systems provided a new interactive interface design environment where children could learn by natural touch, interacting with the digital screen. Tabletop devices also mean that children could work collaboratively. The prototyping phase of the tabletop was first developed by Sony's Future Lab R&D group, and the fully functional product was implemented by technologist Bastian Broecker in 2012. "The tangible tabletop system combines multi-touch capabilities and the unique quality of interaction capabilities of digital technology by following the regular round table collaboration" (Kharrufa et.al., 2013).

Two popular tabletop systems are Microsoft Surface and Siftables (Garber 2012). "The surface is a computer; it looks like a table with a multi-touch technology, and has a high-definition display that allows up to 50 children to work collaboratively" (Garber, 2012). The Siftables TUI platform was developed by MIT graduate students, David Merrill and Jeevan Kalanithi made from "small computers that visualise graphics and sense how users move them and where they are in relation to one another"(Garber, 2012, p.17).

Although this technology supports natural interactions and enables collaborative learning, it can raise several challenges in the classroom: teachers may need to spend a large amount of time designing learning activities, and they need to control the technology, and monitor its use with students (Kharrufa et.all, 2013).

Digital Tablets

Tablets are more personalised and seamless devices which allow students to interact with a natural touch screen using their fingers. This technology has been used in kindergarten to year-12 classrooms (Simon, 2012). Tablets such as iPads have been used in classrooms for literacy, language acquisition, mathematical reasoning and in other lessons. Tablets provide potentially useful interactive and digital books. Using digital books can support individual readers' text comprehension and engage struggling students in their reading (Hutchison, Beschorner, & Schmidt-Crawford, 2012). In general, reading a digital book requires different skills and strategies than reading a traditional text book, and it requires new literacy skills to read and navigate them (Hutchison, Beschorner, & Schmidt-Crawford, 2012). However, researchers point out that it is important that teachers understand these differences and integrate these new literacies; otherwise tablets can have a negative impact. Simon (2012), for example, provides instances of teachers' disappointment after using iPads in their classrooms (Simon, 2012).

2.4.2 Augmented and mixed reality

The term Augmented Reality (AR) was introduced in the early nineties. Virtual objects are placed within physical reality using techniques first developed by Sutherland and Sproull in their "optical see-through Head Mounted Display (HMD) from the early 1960's which came with complex, real-time, computer-generated wiring diagrams and manuals"(Stapleton, Hughes, & Moshell, 2002, n.p). The challenges of merging the realities with a seamless environment resulted in limited success.

Mixed Reality (MR) was combines optics, graphics generation, video imagery, and computer vision. A video see-through Head Mounted Display (HMD) was developed to more correctly represent the mixing of these realities" (Stapleton, Hughes, & Marshall, 2002, n.p). "Augmented reality applications went beyond the typical aim to create a more seamless interactive MR environment for art and entertainment" (Stapleton, Hughes, & Marshall, 2002, n.p).

2.5 Education technology implementation design

Technologies such as those discussed in the preceding section have been introduced with mixed success and much has been learnt about how to implement education technologies better. One way is to look at this as a design problem. Schools are dynamic organisations with many factors having an influence on classroom teaching and learning (Creemers & Kyriakides, 2007). There are various levels of influence that encourage learning and impact learning outcomes. At the school level factors that impact teaching and learning are school policies on teaching and the learning environment at the school (Creemers & Kyriakides, 2007). At the student and classroom level are the factors related to student achievement (Semple, 2000). At a teacher level, factors which have a potential influence on technology integration into the classroom and on student achievement are:

- ***C*****urriculum**: Mandatory curriculum requirements do not leave many opportunities to undertake activities that do not meet learning outcomes (Haggard, 2011; Martyr, 2013).
- **The right tool for the job**: It is important to match suitable educational technology to learning outcomes. (Martin, 2000; Simon, 2012; Mouza, 2005; Turbill, 2001).
- **Use of technologies to aid learning**: How should teachers use technologies to aid learning and what types of learning we should facilitate with computers? (Clarke & Zagarell, 2012; Simon, 2012; Campbell, 2009; Cordes & Miller, 2000; Mouza, 2005;

Fischer, 2009). Roth and Sanders (1996) stated that using technologies in education can enhance the quality of classroom teaching and meet individual learner requirements. They also noted the potential technologies to turn learning into a collaborative activity. Another study identified that implementing user interface design can lead to better learning outcomes and higher satisfaction of learners (Schär, Schluep, Schierz, & Krueger, 2000; Wager, & Gagne, 1988). A study led by the University of Melbourne also indicated the positive impact of using technologies to improve student learning (Devlin & James, 2010).

- **The physical environment**: Features of the environment enable the use of the technology to be optimised. These may include factors such as space, noise, visibility and more (Haggard, 2011; Martyr, 2013).
- **Maximising use of available resources**: School facilities are limited and ensuring that the funding and resources allocation is carefully planned and executed is essential for the viability of the school (Haggard, 2011; Martyr, 2013).
- **The right teacher**: Teachers who support constructivist learning have been found to strongly align with the use of computers in the classroom. In contrast, the traditional teacher-centred approach seems to have a negative impact on integrating computers into the classroom (Hermans et al., 2008; Francis-Baldesari & Pope, 2008).
- **Up to date information**: Teachers need to be aware of new and emerging technology tools that are available for teaching. Using technology in education "is a journey, not a destination" (Simon, 2012, p. 29; Mumtaz, 2000; Hermans et al., 2008).
- **Effective training**: Suitable and effective teacher training needs to show teachers how to utilise technology to augment their lessons (Clarke & Zagarell, 2012; Simon, 2012; Clements & Sarama, 2002; Ntuli & Kyei-Blankson, 2012; Hayes, 2007; Danielowich & McCarthy, 2013; Campbell, 2009).
- **Ongoing Support**: This may include before, during and after the introduction and training in the technology. Additional lesson plans and suitable software to enhance the learning tool may be required. Technical support must be available when 'things go wrong' (Haggard, 2011; Martyr, 2013).

- **Time for Preparation**: Teachers need time outside class to reassess their teaching practices, to learn about and to be trained in new technologies, and to research and prepare new lessons (Hayes, 2007).
- **Cognitive development**: Using technology can support a child's cognitive development in three ways: (a) it helps create environments where students can learn by doing; (b) it helps students visualise difficult-to-understand concepts and (c) it reinforces traditional developmentally appropriate activities. Students need opportunities to learn by doing via interacting, exploring, and manipulating real world objects (Mouza, 2005).
- **Duration of Exposure to Technology**: This is about the amount of time children should spend using technology. For example, previous studies have shown that "the use of technology in one teacher-directed activity should not exceed 20 minutes" (Simon, 2012, p. 44; Clarke & Zagarell, 2012). Each new technology will need to be assessed for the duration that it can hold a child's attention for any given activity.
- **Novelty**: When does an emerging technology start to lose its interest for the children or can it be reused in various ways so that the novelty does not wane?

Many of these factors have already been recognised as offering either challenges or assistance in the introduction of a new technology into primary education in support of constructivist learning (Semple, 2000; Schunk, 1996; Francis-Baldesari & Pope, 2008; Ackermann, 1996). This research has sought to actively engage students in learning through technology. Each of these areas need to be considered in order to obtain the maximum benefit possible when encouraging school students in their learning opportunities.

Teachers' attitudes, beliefs and skills have been investigated in relation to how they introduce technology to classrooms, especially in terms of 'lack of acceptance' and 'lack of technological fluency' (Bers et al., 2002). However the successful integration of this technology in primary schools depends on teachers accepting humanoid robots. One experiment sought to observe teachers' acceptance of robots when they attended a professional workshop on educational robotics (Fridin & Belokopytov, 2014). The attendees were exposed to a NAO robot located in the lobby and then were asked to answer a questionnaire. There was a diverse range of responses to the questionnaire although in general the reactions and level of acceptance were positive. Several other studies have discussed various aspects of teachers' acceptance but there is still no methodological approach for measuring acceptance (Fridin & Belokopytov, 2014). The Socially Assistive Robotics (SAR) study mentions that intensive research is necessary to diminish the gap between the technology and the end-user (the teachers in this case) (Fridin & Belokopytov, 2014; p.30).

Serholt et al. (2014) describe a large-scale study conducted in Europe looking at teachers' perspectives on the use of humanoid robots in the classroom. The main goals of this study were to ascertain teachers' concerns on the integration of humanoid robots into daily school practice, and to identify the roles a robot might play in the classroom. This study found that teachers' main concerns around the use of this technology were more about fairness of access to the technology and the potential for disruption to other classroom activities. Reich-Stiebert and Eyssel (2016) found that teachers were concerned about the possible disruption by robots of teaching processes in the classroom.

Reich-Stiebert & Eyssel (2016) found that a robot can act as a tutor, that it could be "an engaging tool" for all the students in groups who used it, and that student learning progressed as a result without diminishing the teacher's responsibility. This study made the important point that teachers' involvement in the design process is necessary to understand the complexity of the classroom situation into which the humanoid robot will be introduced.

There are many studies that have focused on teacher and student acceptance and their attitudes towards a humanoid social robot in the classroom (Dillon & Morris, 1996; Fridin & Belokopytov, 2014). "Technology acceptance can be defined as a user's willingness to employ technology for the tasks it is designed to support'' (Dillon & Morris, 1996; Fridin & Belokopytov, 2014, p.23). The acceptance by teachers of this advanced educational robot is a critical issue as technology-enhanced learning and teaching practices are being increasingly introduced in the classroom teaching process (Fridin & Belokopytov, 2014). Without the teacher's acceptance of any advanced educational technology, it cannot be effectively integrated with the curriculum to deliver whatever value it may hold (Zhao, Hueyshan, & Mishra, 2001; Fridin & Belokopytov, 2014). Researchers have shown that several factors can affect the technology integration process. These factors are: "user characteristics, content characteristics, technological considerations, and organisational capacity" (Fridin & Belokopytov, 2014).

Reich-Stiebert and Eyssel (2016) also investigated teachers' attitudes and willingness towards humanoid educational robots. They conducted a survey of 59 German school teachers to observe their attitudes to using robots in diverse learning settings. The results showed that teachers had negative attitudes towards these robots but their findings also indicated a positive association between commitment to technology and teachers' attitudes (Reich-

Stiebert & Eyssel, 2016). They demonstrated that teachers had concerns that robots would add to their workload while on the other hand they expressed fears that robots might be used to replace them. The authors found that these teachers' attitudes were closely relevant to their willingness to use educational technology tools in the classroom and that this was affected by students' opinions about the importance of using technology in school. They stressed that "such research also opens up novel perspectives on how to make use of the potential of education robots most optimally" (Reich-Stiebert and Eyssel, 2016, p.679).

There is no doubt that technology has great potential for facilitating teaching and learning in the classroom, and that teachers do not always use technology effectively (Fridin & Belokopytov, 2014). However, there are still various aspects of teachers' acceptance that have not yet been studied and which need to be considered. Studies about teacher's acceptance of technology still involve teachers passively, mainly through questionnaires about various aspects of acceptance. However, several recent studies have suggested that it is necessary to involve teachers in the design process in order to diminish the gap between technology and its end-users (Fridin & Belokopytov, 2014; p.30; Serholt et. al., 2014). Researchers note that it is empowering for teachers to have others seek to understand teachers' knowledge of the complexity of classroom situations (Reich-Stiebert & Eyssel, 2016). Teachers' knowledge has now been recognised as a key resource and studies are beginning to focus on how participatory design can draw on this knowledge, given that classrooms offer complex situations and teachers are the ones who have experience of the complexity of the classroom environment.

Methodologies and approaches that involve teachers in the design process include participatory design, design-based research and action research. In particular, design-based research offers a way to plan for and to implement design solutions in educational contexts. The next stage in this literature review looks at how participatory design, action research (AR) and design-based research (DBR) can be used for involving teachers in the design process in order to make the technology integration more effective.

2.5.1 Participatory design

Participatory design (Matuk, Gerard, Lim-Breitbart, & Linn, 2016) is a method that can involve teachers closely in the design process. In general, this method is used for gathering design requirements to address user needs. These methods allow teachers to collaborate with researchers and contribute their classroom expertise and knowledge to shape the technology tools to be used within their scope of practice. However, these methods provide little guidance as to how to maintain effective interactions between teacher and researcher in their design partnership. Matuk et al. (2016) mention four strategies for involving teachers into the design process to receive their input: “discussing physical artefacts, reacting to scenarios, and customising prototypes,”(Matuk, Gerard, Lim-Breitbart, & Linn, 2016, p. 79).

Physical artefacts can “illustrate components and interactions more visually and efficiently than text based or verbal representation” (Matuk et al., 2016). These artefacts are useful for expressing and combining various ideas into one representation, which then allows group members to analyse and construct a shared understanding of problems and find possible solutions (Schon, 1983; Matuk et al., 2016). “As with other external representations generated in the design process (e.g., Suwa & Tversky, 1997; Suwa, Gero, & Purcell, 2000; Suwa, Tversky, Gero, & Purcell, 2001) the physical artefacts can also drive some discussion of ideas that had never been considered before” (Mogensen, 1992; Trigg et al., 1991). When the researchers present a mock-up, teachers can imagine and discuss what it might be like to use, and in this way the teachers’ actual goals and the contextual needs of using the technology become real for the researchers. Teachers and researchers can work together to refine specifications and their expectations of the final product. There are several digital tools available to construct dummy interfaces and various professional prototyping applications on the market (Matuk et al., 2016).

Scenarios are the narrative explanation to users of a particular situation that reflects the design requirements. Scenarios present some possible design features of a new tool or interface from within the initial design concept (Carroll & Rosson, 1990). Effective scenarios offer concrete pictures of an individual user’s aims and activities in a specific situation. Scenarios are purposefully incomplete so as to allow users chances to think and imagine “possible alternative roles of technology” (Carroll & Rosson, 1990). Scenarios are used to create open discussion from teachers about their own ideas and expectations of using technology in the classroom. Teachers can then reflect on how the proposed scenario relates to their own real classroom practice, and they can discuss or expand on more specific details from a specific starting point (Matuk et al., 2016).

Prototypes are “low-fidelity” versions of an interface design, which demonstrate the preliminary design and test the feasibility of ideas (Matuk et al., 2016). This prototyping stage provides a low-cost way for experimentation with the design ideas. Users receive a real impression of the design and they can reflect on their specifications and requirements (Matuk et al., 2016). “Prototypes are an important part of the design process. They give designers physical embodiments of their ideas and allow them to explore the functioning of particular aspects" (Matuk et al., 2016, p.96). The Agile methodolgy when used for development emphasises rapid prototyping and early risk mitigation. This Agile methodology helps designers work with the users on a regular timetable to receive feedback, which can be used as inputs into the design to inform succeeding iterations and thus reduce the amount of time and effort spent in visionless design process (Matuk et al., 2016).

2.5.2 Action research

Action research involves "a change of organisational situation by the active participation of a researcher/facilitator" (Elliot, 1991). According to Kemmis (1986,p.9, 2012), action research "preserves a notion of the external researcher who provokes or facilitates or in some way manages the research process, and who maintains a kind of academic disinterest about what occurs in the research". This outsider location may refer to the real-world context, for example in industrial/social/educational settings where the academic facilitator of action research conducts their research activities. The field of action research uses a systematic approach to make a connection between organisational psychology and practical problems because of their understanding of existing organisational issues.

Action research (AR) is a practical approach that allows researchers to explore an education problem with the goal of developing a solution. AR is a set of systematic procedures conducted by the teachers themselves to collect information and improve the way an educational setting or program currently operates (Creswell, 1999; Creswell & Miller, 1997). In this research, teachers aim to improve their classroom practice by identifying and studying their own issues or problems. Teachers reflect on real classroom problems, collect information and analyse data about them, then implement change and solve the problems based on their findings. Researchers sometimes address a local and practical problem, such as a classroom issue for a teacher, but also look at issues requiring change across an entire school or district. In general, using AR "researchers seek to empower, transform, and emancipate individuals from situations that constrain their self-development and self-determination" (Creswell, 1997, p.577).

AR displays the following characteristics (Creswell, 1997, p.578; Mills, 2011) in that it:

- Encourages change for improvement in schools
- Involves many individuals and teachers
- Allows individuals to collaborate to develop a project

- Redefines teachers and educators as learners who are seeking to identify the gap between best educational practice and their real classroom issues
- Inspires educators to reflect on their current practice
- Supports a process for testing new ideas

2.5.3 Design-Based Research

Ann Brown (1992) introduced the idea of design-based research (DBR). The terms “design-research” (Oha & Reeves, 2010), “design-based research” (Kelly et al., 2008) and “development research” (Conceição, Sherry, & Gibson, 2004) have all been used to describe this methodology, but the most popular designation is design-based research. DBR aims to enhance both the theoretical contributions and the “public value of educational technology research” (Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006). The use of DBR is increasing in education contexts, especially for the primary school context with technology interventions (Anderson & Shattuck, 2012).

As “learning is too complex a phenomenon for any one discipline, theoretical perspective, or research method, DBR is premised on the notion that we can learn important things about the nature and conditions of learning by attempting to engineer and sustain educational innovation in everyday settings” (Bell, 2004, p.243). DBR is a series of iterative approaches, rather than an approach, which can produce new theories, artefacts, and practices that have the potential to “influence learning and teaching in real-life settings” (Barab & Squire, 2004).

“Design based research is not just a type of formative evaluation” that allows educational researchers to understand “the ecological validity of theoretical claims generated in the laboratory” (Barab & Squire, 2004, p.5). Generally, “formative evaluation methodologies” are used to improve the value of a specific designed artefact whereas DBR is focused on “using design in the service of developing broad models of how humans think, know, act and learn; that is, a critical component of design-based research is that the design is conceived not just to meet local needs, but to advance a theoretical agenda, to uncover, explore, and confirm theoretical relationships” (Barab & Squire, 2004, p.5).

According to Barab and Kirshner (2001), “the goal of these researchers/educators/designers moves beyond offering explanations of, to designing interventions for"(Barab & Squire, 2004, p.4). They go on to note parallels with “pragmatists such as Dewey, Pierce, and James” (Barab & Squire, 2004, p.4).

Part of design-based research is that it knows that teachers are sometimes very busy and not trained to conduct rigorous research. On the other hand, educational researchers often do not know enough about the complexities of the classroom and aspects such as the culture, technology, purposes, curriculum alignment, and pedagogy. Thus, a partnership between teachers and researchers needs to be developed that “negotiates the study from initial problem identification, through literature review, to intervention design and construction, implementation, assessment, and to the creation and publication of theoretical and design principles” (Anderson & Shattuck, 2012, p17).

According to Allan Collins (1982) and Ann Brown (1992), who first conceived of the notion of “design experiments” in education, the methodology has the goal of bridging the unfortunate gap between educational researcher and classroom practitioner (Flannery & Bers, 2015, p.198). DBR helps to build a learning theory with practical implications in the classroom context by designing an educational intervention and then studying why this intervention works and how it relates to learning outcomes. DBR methodologies are also useful to explore and identify how a technological innovation affects learning and educational practices and it can offer a model for broader educational improvement. Through interventions and in-context study, DBR brings the development of learning theory closer to the complex classroom environment where learning actually takes place. DBR contributes to educational learning theory in a meaningful ways, and simultaneously improves learning tools and student learning outcomes (Flannery & Bers, 2015, p.198).

DBR is conducted in close collaboration with teachers and students. Research teams are generally built up from multi-disciplinary areas, and each team member in varying degrees according to context provides significant input to the team based on the depth of their expertise. In this way a new design or innovation, whether in technology, in curriculum or activity, or in teaching or interaction style, is implemented through researcher-practitioner collaboration at the appropriate level.

DBR is an iterative methodology. Each cycle of intervention analyses and refines both the intervention and the working theory of learning. DBR starts by identifying a local problem, documenting its characteristics, and positing an instructional theory to enable the construction of an educational and technological intervention. The results of the intervention are documented and relevant data collected. Both the intervention and the instructional theory are evaluated during and following each implementation stage. “Iteration cycles of intervention, evaluation, redesign, re-implementation and more process continue as is necessary to build the instructional theory or for as long as is practical" (Flannery & Bers, 2015, p.200).

The TangibleK project was run by Flannery & Bers (2015) to create an educational robotics program, which was directed at and implemented with children and teachers in preschool to second grade. The project focused on "curriculum, assessment tools and a robotics construction kit with a developmentally appropriate interface" (Flannery & Bers, 2015, p.202). The curriculum and the robotics kit were used to teach children creative ideas and skills, which were attained by applying computational thinking in a robotic context. Over 600 children and more than 20 teachers across 6 schools and 2 museums participated in this study. The TangibleK project had five iterations following the DBR methodology and each cycle helped them to refine the curriculum, the technology, and the methods for assessing the children's learning. This project used a mix of assessment methods developing from its starting level to more systematic investigations in classroom and laboratory settings. By the end, the project had refined a programming technology, led to the adoption of a curriculum, created assessment tools for different age ranges and expanded understanding of children's learning processes in programming, robotics and computational thinking.

One of the core challenges of studying technologies in a learning context today lies in the need for continued refinement of methodologies such as DBR. Teachers need to be closely involved in the design process because they have a broad knowledge of teaching and learning practices and understand the complex classroom setup. Based on this literature review, this study has identified that there is a lack of methodology that actively involves teachers (as end users) and experts in order to capture their complex classroom knowledge and expertise as inputs to the design process. The methodologies found in the literature mainly showed teachers being involved passively in investigations into education technology integration.

The next section looks at what kind of frameworks are available to draw the broad complex knowledge of teachers into the design process using DBR. Technological Pedagogical Content Knowledge (TPACK) and SAMR are common frameworks used during technology integration to understand the knowledge that teachers possess (Bunz, 2016). It is argued that teachers' knowledge about technology implementation is best classified and evaluated in terms of the TPACK framework.

2.5.4 Technological Pedagogical Content Knowledge (TPACK)

Technological Pedagogical Content Knowledge (TPACK) was developed by Mishra and Koehler (Mishra & Koehler, 2008). It refers to “the synthesised form of knowledge created for the purpose of integrating educational technology into classroom teaching and learning practices” (Mishra & Koehler, 2008; Bunz, 2016). TPACK has three main elements: “content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK)” (Mishra & Koehler, 2008). The CK represents only the subject matter, while the PK is associated with the students’ learning, so methods, learning theories, and assessment approaches used to teach any subject regardless of content. The TK is about how to use educational technology tools, whether software or hardware. The interaction between these three core forms of knowledge creates another three forms of knowledge, as shown in Figure 1: “pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK)” and these then combine to form TPACK (Mishra & Koehler, 2008). The PCK describes content knowledge and follows pedagogical strategies to make the content/subject matter more understandable for the learners. The TPK focuses on how to use different types of technologies to enable teaching or learning approaches to curriculum areas. The TCK is about “how to use technology to create the content in different ways” for (Mishra & Koehler, 2008). Finally, TPACK shows how to use educational technology tools “to teach and facilitate knowledge creation on a specific subject/content/topic” (Chai, Koh, & Tsai, 2013, p. 32).

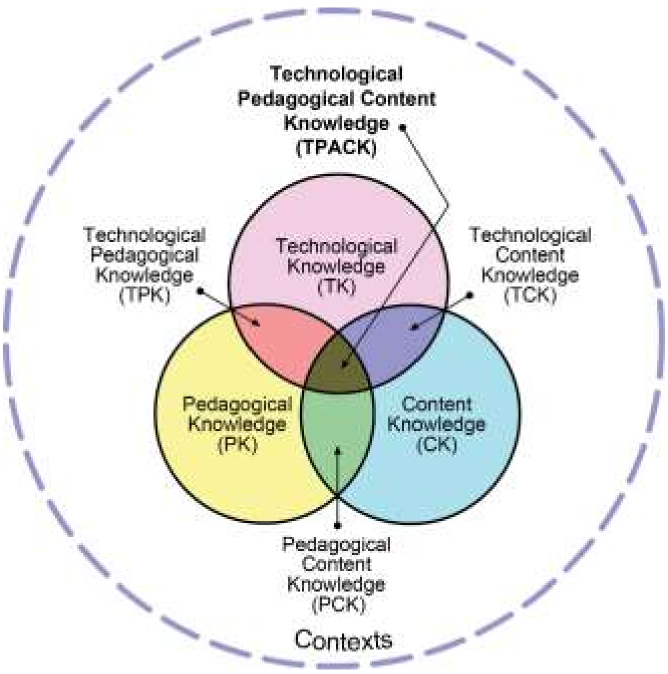


Figure 2.1: The TPACK framework. (Chai, Koh, & Tsai, 2013, p. 32)

There are seven dimensions in this framework (Chai, Koh, & Tsai, 2013; Schmidt et al., 2009, p. 127).

"TPACK includes the understanding of how best to represent concepts using technology, pedagogical strategies that can be enhanced using technology, knowledge of what concepts are more difficult to learn and how they can be addressed more effectively using technology, understanding of students' prior knowledge, and knowledge of how to use technology constructively" (Chai, Koh, & Tsai, 2013, p. 32).

The TPACK framework also takes into account learners' understanding and involvement in learning in terms of assessment (see Figure 2; Webb, 2014). Students' pedagogical issues are connected to the environment and interactions, which "create affordances for learning and where formative assessment is embedded students act as instructional resources for each other" (Webb, 2014, p.278). The interactions between teachers, students and technology enable the learning environment. Teachers' pedagogical reasoning is connected to the affordances for learning.

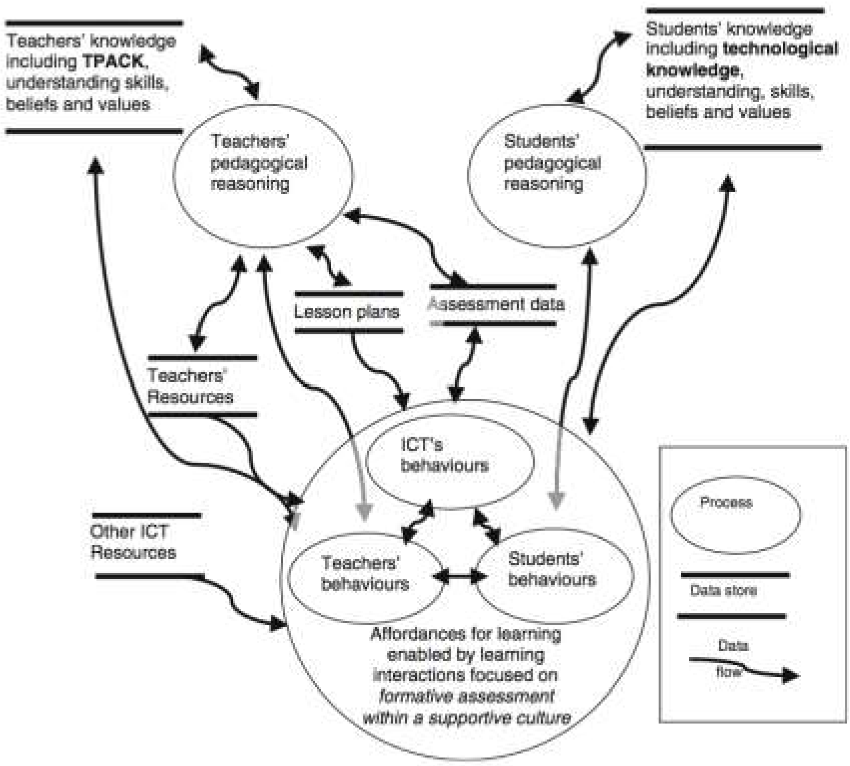


Figure 2.2: A revised framework for pedagogical practices relating to ICT/Educational technology use. (Webb, 2014, p.278)

However, the extent of the benefits derived from the affordances for learning depends on how well teachers use ICT resources in classroom activities. Successfully integrating ICT and educational technology resources into the classroom requires deep knowledge and expertise from teachers. While the integration of ICT into classroom practice is beneficial for students as it motivates them in their learning, the implementation of ICT in the classroom is still a challenge for teachers as it makes their role more complex. In reality teachers use only a small subset of the technologies which might enable a more beneficial learning environment (Webb, 2014).

2.5.5 The SAMR framework

The SAMR (Substitution, Augmentation, Modification and Redefinition) model

This model, developed by Puentedura, shows four levels for the use of technology in the classroom and it is designed to encourage practitioners to improve the quality of technology use (Puentedura, 2014)

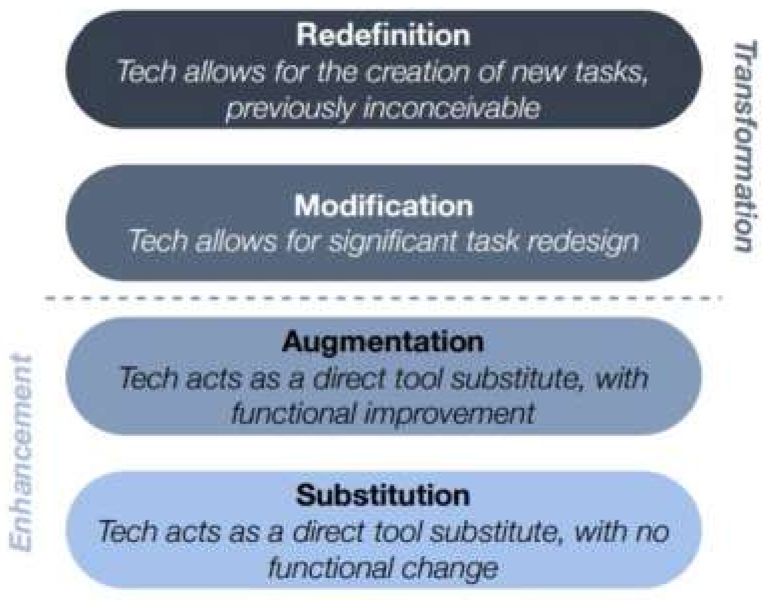


Figure 2.3: The SAMR model (Bunz, 2016, p.7; adapted from Puentedura, 2014)

Romrell, Kidder & Wood (2014) defined substitution as “the use of technology as a substitute for learning activities without adding any functional change” (cited in Bunz, 2016, p.6). Listening to lectures online is an example of this.

The augmentation stage is the use of technology as a replacement tool but with some improvements. An example is where a text messaging feature can help students learn vocabulary or where they use video/audio as materials in context (Romrell, Kidder, & Wood, 2014; Bunz, 2016).

Kidder & Wood (2014), defined modification, as "the use of technology to re-design learning activities" (Bunz, 2016) where for instance a text messaging feature could send notifications to students updating them on simulated events, generating simulated conversations from their responses. This type of conversation with its interdependencies would allow the "simulation to be redesigned, and provided students the opportunity to participate in real-time decision making" (Bunz, 2016, p.6).

The final level in this model is redefinition, which uses technology to create completely new types of task. For example, a program was developed to teach English to Chinese students (Bunz, 2016). It used a GPS to locate the student and then English expressions related to the objects and places in that part of the world would pop up as the images were viewed through the phone camera (Bunz, 2016, p.6). This type of activity is not possible without a phone camera and GPS. "Using tools within the substitution and augmentation categories can enhance students' learning, whereas using digital tools within the modification or redefinition categories has the potential to transform the learning experience" (Romrell, Kidder & Wood, 2014; Bunz, 2016).

The TPACK framework is the most useful for this study because it provides a systematic approach from the teachers' perspective to the types of knowledge required to integrate technology into the classroom. SAMR (Kidder & Wood, 2014), on the other hand, is more about the various levels of technology tools and encouraging their use in the classroom.

2.5.6 Recent studies that merge TPACK and DBR in robotics education

Moorhead et al. (2016) undertook a study to support teachers with their professional development (PD) because of the increasing need for them to use advanced technologies in meaningful and effective ways in their learning environment. The main goal was to "evaluate the use of situated learning for the purposes of PD by means of design-based research (DBR)" (Moorhead et al., 2016). Other goals were to look at the effect that the PD had on the teachers' knowledge and understanding when it came to develop and implement lessons using LEGO EV3 kits; and to see how successful the iterative process of DBR was when it was used both to evolve the PD and to refine the existing lessons. The DBR methodology used iterative cycles of the learning environment to help develop the learning theories and the artefacts used by the educators. This process allowed the educators to identify which aspects of theory worked better in their learning environment as well as the best way to use learning theory to produce an effective outcome. In this study, the TPACK framework itself was selected as the first topic to introduce to the teachers because it related to the PD and because it showed how new technologies can benefit education when these technologies were used appropriately.

Rahman et al. (2017) conducted a study to look at the extent of teachers' and students' willingness to trust robots. Here they used the TPACK framework and designed new learning activities by carefully adopting educational robotics technology to facilitate the teaching of challenging science and maths content. This study used a design-based research (DBR) approach "wherein iterative changes improved the lessons as the project progressed from planning to implementation" (Rahman et al., 2017). The researchers observed how much teachers and students were willing to "believe in, understand, and accept the solutions provided by robots" and how far they would rely on the robots' guidance and influence in STEM teaching and learning (Rahman et al., 2017). They identified several aspects of robots that affected the level of trust from teachers and students. Other related studies have been conducted into the extent of "users' trust" when they work with robots in terms of "the effectiveness of the services provided by the robots and the efficiency of the human-robot collaborative interactions" (Rahman et al., 2017).

2.6 Conclusions

Educational technology is becoming widespread in schools and children are growing up with it. This review has described its use in general terms and focused in particular on the potential for humanoid robots to influence the learning environment. In such an event it will be essential to change pedagogical practice. DBR provides a methodology to enable research that can inform such changes.

Many teachers have already faced challenges integrating educational technology into their classrooms and felt that they were "inadequately prepared for subject-specific use of technology integration and [that] a robust theoretical framework is lacking" (Chai, Koh & Tsai, 2013, p.31). The TPACK theoretical framework was introduced to further explore this problem. In this research, DBR methodology will be used to enable the application of the TPACK framework, to access teachers' knowledge of the complexities of the classroom. Combining TPACK and DBR methodologies in the context of robotics and education is a recent trend. The core research problems of this thesis address current issues around the introduction of humanoid educational service robots into the classroom.

3 Research methodology

This chapter describes the design based research (DBR) methodology used in this thesis and explains the rationale for using it. The review of the literature in Chapter 2 discussed central debates in relevant fields, including possible benefits of using humanoid robots in primary education and challenges associated with introducing educational service robots into classrooms (Kennedy et al., 2016; Reich-Stiebert & Eyssel, 2016; Ruzzenente et al., 2012; Kanda, Shimada & Koizumi, 2012; Cabibihan et al., 2013; Vircikova et al., 2012; Magyar et al., 2014). As noted in Chapter 2, recent research has stressed the complexity of classroom settings and the subsequent need to incorporate knowledge of pedagogy and curriculum content into technology implementation design (Fenstermacher, 1994; Mishra & Koehler, 2006). For this reason, this thesis draws on teachers' technological, pedagogical and content knowledge (TPACK) in the implementation design process (Lee & Hollebrands, 2008; Chai, Koh & Tsai, 2013; Mishra & Koehler, 2006).

The discussion below focuses on methodological issues around the central question: *How can technology implementation design be optimised for the introduction of a humanoid educational service robot in primary school classrooms?* An overview of DBR and its characteristics is presented in Section 3.1 with discussion of its pros and cons and comparisons with other methodologies used in educational technology research. The four steps of DBR are described in Section 3.2.with detailed descriptions of each step and the associated iteration cycles followed over the course of this doctoral project. A concluding summary is presented in Section 3.3.

3.1 Introduction to design based research

3.1.1 Characteristics of design based education research

Design based research (DBR) in education was first proposed by Brown (1992). It aims to create a bridge between education research and classroom practitioners in order to transform educational research into improved practice (Anderson & Shattuck, 2012). DBR methodology focuses on a real and local educational context and collaboration between researchers and practitioners in the design and testing of a significant intervention, usually involving multiple iterations. The design process and its evaluation often use mixed methods (Anderson & Shattuck, 2012).

Grounding the research in a local context provides relevance and validity to the investigation, and ensures that the outcomes are aimed at improving practice. For example, in the current research project, the local context is primary school classrooms in Melbourne, Australia. In this context DBR therefore required collaboration between researchers and teachers. This was shown to be necessary in the case of this project because on the one hand, educational technology researchers are not always knowledgeable about the full range of complexities of classroom pedagogy and on the other hand, teachers are not often trained to conduct broad educational research into technology integration. In addition, as noted in Chapter 2, education technology implementation design has a problematic history arising from lack of informed planning and a failure to take into account pedagogical, curricular and technological complexities of education contexts. This thesis argues that design principles such as participatory design with stakeholders, retiring risk early and extensively evaluating user experience before implementation could help to optimise the introduction of educational service robots and avoid the kinds of costly mistakes that have characterised the introduction of other education technologies.

DBR teamwork starts with knowledge sharing and initial problem identification, and extends to intervention design and development, implementation and evaluation (Brown, 1992; Anderson & Shattuck, 2012). This project incorporated primary school teachers' knowledge of relevant technology, pedagogy and content into the implementation design while keeping in mind the central DBR pragmatic requirements, stressed by Brown (1992). These noted that a successful intervention must able to move from the experimental classroom to the average classroom learning environment and to support average students using suitable tools (Brown, 1992, p. 143).

The creation of design begins with the local context; it is derived from the relevant literature, theory, and practice from other contexts, and it represents a development solution. Interventions can take many forms, for example, a learning activity, an assessment instrument, a technological intervention and so on. This project focused on the design of a learning activity for primary school students using a humanoid robot. The purpose was not to design a learning activity as such; the purpose was to find a way to evaluate the potential of the robot as a tool for constructionist learning in a primary classroom context. As discussed in Chapter 7, the evaluation of the prototype learning activity as it moved through its multiple design iterations and converged on more optimal solutions, revealed the scope and limitations of the humanoid educational service robot in ways that will improve implementation outcomes further downstream.

In DBR, the design is the main focus for evaluating the quality and results of the research project. Mingfong et al. (2010) identified various design characteristics which need to be aligned in a significant intervention (Anderson & Shattuck, 2012). These include 'the affordances of the chosen instructional tools' and 'frameworks for learning' (Anderson & Shattuck, 2012, p. 16). In this project, the evaluation of the learning activity focused on the robot's affordances in terms of their ability to support a constructionist learning framework.

Design practice normally follows procedures through the creation and development of prototype and testing, iterative refinement, and continuous evolution until the design reaches a satisfactory level (Anderson & Shattuck, 2012). In design-based interventions, there is always scope for researchers to improve design and evaluation with the aim of achieving more effective outcomes. However, there is a challenge in this methodology: it is difficult to predict when the research cycles are completed (Anderson & Shattuck, 2012; Brown, 1992; Barab & Squire, 2004).

DBR is pragmatic in that it can involve mixed research methods, where educational researchers can use different research tools and techniques based on their needs and apply their outcomes of the research to "a reality that is both plural and unknown"(Anderson & Shattuck, 2012, p. 17).

3.1.2 Comparisons between design based research and other educational technology implementation research methodologies

The next section further justifies the choice of DBR by discussing differences between various methodologies that support educational research, especially in terms of technological interventions. It presents comparisons between firstly, DBR and action research, secondly, DBR and psychological experimentation in education and thirdly, DBR and conventional design methodology. It also discusses criticism of design based research.

Comparison between DBR and action research

Action research and DBR share a common 'meta-paradigm logicality' (Anderson & Shattuck, 2012). Researchers and practitioners sometimes have trouble distinguishing between action research and DBR because "they share many epistemological, ontological, and methodological underpinnings"(Anderson & Shattuck, 2012, p. 17). However, in action research, the design not only aims to meet local needs, but it can also follow a theoretical agenda; on the other hand, DBR focuses on local needs and the research must fit the real world context.

There is also a difference in terms of the researchers who run a study: action research is generally carried out only by teachers while DBR involves teachers, researchers and developers in taking the design to a satisfactory level. In action research, teachers often focus on challenges with the aim of achieving a research result that will make a difference to their educational practice.

Comparison between DBR and Psychological Experimentation (Barab & Squire, 2004)

There are also differences between DBR and Psychological experimentation: psychological experimentation (PE) is conducted in a laboratory while DBR's usual focus is real life settings such as classroom settings. Apart from the context of use, PE involves a single or a highly constrained number of dependent variables whereas DBR involves multiple dependencies. The research focus in PE is to identify a few variables and make them constant; DBR focuses on characterising the situation, which is the opposite of testing a hypothesis.

The strategies for procedure and learners' participations are also different: PE uses fixed procedures; DBR involves flexible design revision, where iterations happen until the design is successful in practice. PE does not involve learners interacting in the design process; however, DBR involves complex social interactions with various stakeholders who share their ideas, knowledge and expertise. The role of participants in psychological experimentation is solely as subjects, while DBR brings researchers, practitioners, and designers into the design process to incorporate their various kinds of expertise to meet the aim of effective design.

Comparison between DBR and design methodology

In general, design is defined as a goal-directed and problem-solving activity, which can result in the creation of something new and useful (a process or a product) (Luckin & Luckin, 2013). According to Rowland (1993), the definition of design in terms of educational or instructional design, should show that it is directed toward the practical purpose of learning; it should result in the creation of new instructional materials or systems that give students the opportunity to learn (Rowland, 1993, cited in Luckin & Luckin, 2013).

In educational contexts, design work can now be conducted by multi-professional teams that may include practitioners, students, educational researchers and development teams. A participatory, or user-design approach can be used for design work, involving the end user in significant design decision making. In general, end-users comprise those for whom the instruction is intended; in instructional/educational design, then, end-users can include teachers and/or students, depending on the specific design. DBR is an approach that includes participatory design in its design method and involves incorporates strong involvement of the end user (Luckin & Luckin, 2013).

Although it can incorporate all of these design principles, DBR is usually described as a research methodology, not a design methodology.

Pros of DBR:

DBR is not just an approach, it is a series of approaches, which can produce new theories, artefacts, and practices that have potential impact on learning and teaching in real settings (Barab & Squire, 2004). This methodology seeks to integrate practical and theoretical considerations so that educators can derive results based on theories of learning and teaching.

DBR is not just a way of offering formative results based on theoretical claims; it also introduces researchers' expectations, allowing them to adjust various aspects of the design context to test and contribute theory in naturalistic contexts (Barab & Squire, 2004). In this way, DBR has the potential to involve flexible design revision. Anderson & Shattuck's (2012) review of DBR found that DBR is especially attractive for use in K–12 education contexts and with technological interventions. Many studies have focused on interventions in terms of improved outcomes or student attitudes; Anderson & Shattuck showed evidence of matches between successful testing of technological interventions and a focus on context and concluded that DBR is becoming more useful in educational research.

Cons of DBR:

DBR has some limitations, however. Barab and Squire (2004) argued that if researchers are closely involved in the design process during anthropological research or qualitative research, then none of these methods can claim to remove the researchers' bias from the research process; however they acknowledged that such researchers also develop deep knowledge and understanding of the context (Barab & Squire, 2004).

One particular challenge of using a DBR lies in defining a project's scope and timeline because the temporal scope of a DBR project depends on the requirement of multiple iterations. An important criticism of DBR has been that it is difficult to establish a project's duration because educators cannot predict beforehand when the iteration process will be completed (Barab & Squire, 2004; Reeves, 2006; Flannery & Bers, 2015). This means that researchers may have to limit their focus to a reduced number of stages of the design phase, as turned out to be the case in this project.

A comparison between psychological experimentation, action research and DBR shows the merit of following a DBR approach to investigate the implementation of a humanoid robot in a primary classroom for learning and teaching purposes. This project involved teachers, researchers and a development team sharing their expertise over the course of the design process. The next section discusses the DBR processes relevant to this study.

3.2 Design process

DBR in education follows a series of steps in defining problems and researching, designing, implementing and evaluating solutions. This process can continue until a satisfactory level of outcome is achieved (Flannery & Bers, 2015). This project followed the following DBR based steps (Reeves, 2006):

- Step 1: problem definition
- Step 2: analysis of practical problems by researcher teams
- Step 3: development of solutions
- Step 4: construction/evaluation/iteration cycles

Table 3.1, below, shows these four steps of DBR as they were taken over the course of this project and the various combinations of elements, methods, participants, materials and outcomes that were associated with each of them (Reeves, 2006)). In Column 1 of the table, a ‘step’ is associated with the specific DBR goal that needs to be achieved at that stage; as shown, each of the iterations in Step 4 required a different, revised goal.

In Column 2, the ‘elements’ represent the conceptual components of the research design that supported the achievement of each of the goals. In DBR, such elements can be frameworks, guidelines, design principles and other abstract systems.

As shown in Column 3, DBR allows multiple methods for research projects. Column 4, ‘participants’, details how actors were engaged in the design process (directly or indirectly) in creating or providing feedback or implementing design. Columns 5 and 6 show the ‘materials/resources’, including the physical artefacts that were part of the intervention, and the ‘outcomes’ that identified possible research outputs for each specific goal.

More detailed descriptions of each step and its associated procedures and components are given in the sub-sections below. In addition, because of the multiple methods used in this study and the strategic changes to the research design, Chapters 4, 5 and 6 also contain further detail in relation to methods, participants and procedures.

Step	Elements	Method	Participants	Materials	Outcomes
Step 1:Define a problem	- Statement of the problem from a literature review - Research questions - Literature review of background information	Comprehensive literature review	Educational technology researcher finds the gap or problem of technology implementation in education	- Microsoft word for documentation - Library and Online library for collecting literature	A central problem is identified: How can technology implementation design be optimized for the introduction of a humanoid educational service robot into a primary school classroom?
Step 2: Analysis of practical problems by researchers and practitioners in collaboration	- Teachers' TPACK knowledge - Theoretical framework - Draft of relevant design guidelines for technology implantation in education	- Literature review - User requirements elicitation with the involvement of practitioners (Interviews)	Educational technology researcher work with practitioner (primary school teachers)	- General information and Informed consent - NVivo software for transcribing interviews and analysis - Documentation	- TPACK is used as a theoretical framework - Teachers' requirements are collected, based on their pedagogical, content, and technological knowledge. - Teachers' preparedness of technology use in the classroom is identified.
Step 3: Development of solutions	- A skeleton design solution based on teachers' TPACK knowledge of technology implementation in classroom - Detailed design specifications following the design guidelines, theoretical framework and requirements obtained from teachers	- Skeleton design - Agile design process for early risk mitigation	Educational technology researcher and educational practitioners	Documentation	A Learning activity is developed that uses a humanoid robot and is designed to fit into the curriculum
Step 4: Implement (and iterate) prototype learning activity (Construction: Iteration 1)	- Learning activity design informed be knowledge of language and literacy learning - Knowledge of Software development - Prototypes	- Agile design process - Scenarios	Software development team and the educational technology researcher	NAO choregraphe software, and Python	Pre-evaluation of learning activity in terms of risk assessment
Step 4: Test the learning activity and measure learning outcomes of pupils. (Construction: Iteration 2)	- A learning activity for primary school pupils, where they can learn from the humanoid robot in a controlled setting. - Testing of the learning activity with children in the controlled setup - Design evaluation	- Agile design process - Observational study - Video as a method - Demographic questionnaire	School pupils and educational technology researcher	- Humanoid robot - Laptop, NAO choregraphe software, cards	- A learning activity is tested with children - Children's learning progress in terms of their age, and technology experience is evaluated. - Children's learning outcomes is compared with those arising from use of traditional methods.
Step 4: Test pupils in the classroom environment (Construction: Iteration 3)	- Testing OF this activity with children in the classroom environment where teachers will monitor them - Assessment criteria - Design evaluation	Observational study	Pupils, teachers, and educational technology researcher	- Classroom setup - Humanoid robot - Laptops - NAO choregraphe software - Set of activities - Assessment criteria	- Teachers TPACK knowledge is supported for effective implementation of learning activities with the humanoid robot. - Children's learning outcomes are evaluated

Table 3. 1: The steps of DBR for this research (adapted from Reeves, 2006)

3.2.1 Step 1: Defining the problem

The research problem was identified using a comprehensive literature review (Chapter 2), which looked at how educational technology supports teaching and learning practices and the learning outcomes of students (Bers et al., 2002; Mishra & Koehler, 2008; Campbell, 2009; Simon, 2012; Clarke & Zagarell 2012) and examined issues in previous research regarding the effective integration of educational technology tools in classrooms (Flannery & Bers, 2015; Kanda, Shimada, & Koizumi 2012; Kennedy, Lemaignan & Belpaeme, 2016). The problem identified from the literature was generalised beyond the local context in that, as noted above, the main research question derived from this review became: *How can technology implementation design be optimised for the introduction of a humanoid educational service robot in primary school classrooms?*

The humanoid education service robot studied in this project was the NAO robot manufactured by Aldebaran. The manufacturer's technical specifications for the NAO humanoid robot are presented below to introduce the robot's capabilities.

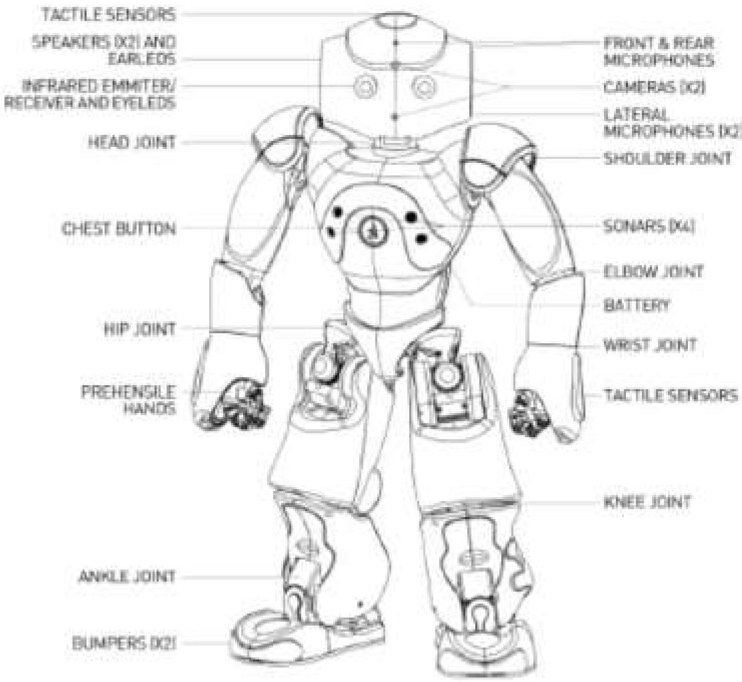


Figure 3.1: Capabilities of the NAO robot (Hughes, 2013)

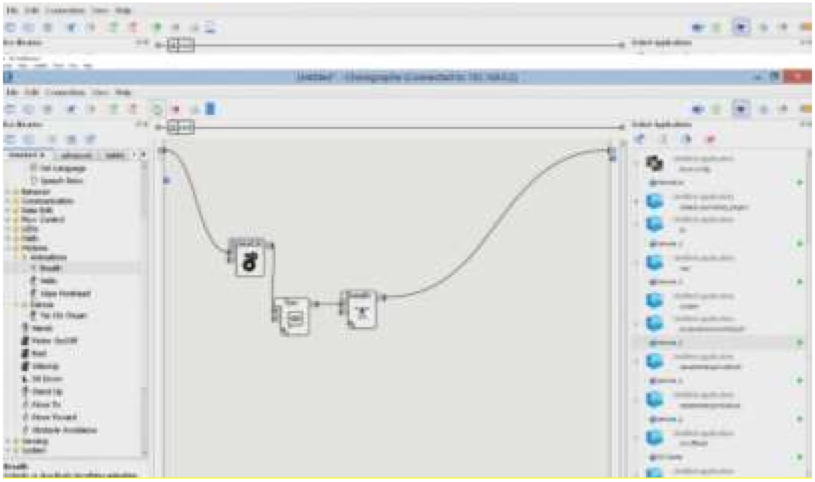


Figure 3. 2: The Choreograph of the NAO robot shows the flow of the conversation program, simple drag and drop commands

The NAO robot is 58cm tall when standing and it includes two cameras, four microphones, two IR emitters and receivers, one inertial board, nine tactile sensors, eight pressure sensors, a voice synthesiser, LED lights, and two speakers. These details are shown in Figure 1 (Hughes, 2013). The NAO robot was programmed using the Choreographe development software suite (Figure 2), which is a drag and drop editable programming tool with a 3D simulator using C++ libraries or Python and .Net.

3.2.2 Step 2: Analysis of practical problems by researchers and practitioners in collaboration

This project drew on learning design principles for conceptualising the learning technology in the context of the learning environment (McKenney & Reeves, 2012; Herrington, McKenney, Reeves, & Oliver, 2007; Luckin & Luckin, 2013). Context is important for design work, and particularly so for learning design (McKenney & Reeves, 2012). As the initial research problem was: *How can technology implementation design be optimised for the introduction of a humanoid educational service robot in primary school classrooms?*, answering this question involved design based research because the challenge of integrating a humanoid robot into hypothetical and generalised ‘classrooms’ needed to be envisioned in terms of a real classroom context and answered in close collaboration with real classroom teachers. To explore this as a practical problem for effective integration of the robot into the classroom, it was necessary to involve primary school teachers and use their input in designing the evaluative prototype learning activity central to this project.

Secondly, an education technology intervention or experiment needs to be placed in a context that takes into account current theories of learning and teaching. A (micro) theory of learning should account for how and why learning evolves over time, and how it would be affected by the pedagogical-technical intervention being evaluated (McKenney & Reeves, 2012). To gauge the potential impact of technology in education, it is important for designers to determine how technologies will be used to facilitate learning. A learning technology is a powerful tool, "but one that may not be appropriate in all situations and used inappropriately, technologies may actually hinder learning" (Cook, 2007, p. 39).

Each technology tool should therefore have a stated purpose in the learning environment and it should be linked to pedagogy (Mereba, 2003). For example, a challenge exists when designers try to design instruction for a highly interactive and/or constructivist environment using a very linear, structured model. Der-Thanq, Hung & Wang (2007) mentioned that a learning activity might not match the desired learning outcomes because of a lack of design tools and methods to support new learning approaches. Designers may inadvertently use unsuitable design methods, such as task analysis, to design non-traditional activities such as collaborative projects. To solve this challenge, designers need access to current and progressive pedagogies and learning theories and to match them with new design tools and methods that support them.

A learning design must also have an envisioned learning trajectory. According to Roschelle et al. (2010), a 'curricular activity system' should be designed to support an 'activity' that not only identifies what students and teachers can do, but also guides participants in fulfilling their learning objectives, taking into account available materials, the intended use of tools, and the roles that agents play in the system. Instructional learning goals also depend on students' learning outcomes over time so curriculum alignment is an important factor in ensuring that the resulting design will have an impact on the learners. Assessment needs to be taken into account, and pedagogies that emphasise learner-centred design, collaboration, student engagement and active participation and problem solving activity need to be matched with relevant learning outcomes. As well as overarching curricular documents (Roschelle et al., 2010), teachers' broad knowledge of content (including curriculum subject matter and assessment) needs to come into play here, so the researcher sought to represent these as 'requirements' to input into the technology implementation design by working closely with teachers to collect this information about how they envisaged using the humanoid educational service robot in their classrooms (see Chapter 4, Section 4.7).

Finally, Step 2 needed to define more closely how to explore the extent to which more technical features of the technology itself might present challenges to 'real teachers' in 'real classrooms' . As noted in the literature review, teachers' perceived 'lack of technological fluency' as a problematic aspect of technology implementation design has been intensively researched over the past two decades, along with notions of teachers' 'non-acceptance' of technology (Bers et al., 2002). However teachers' preparedness to use an educational technology involves a complex set of factors, and, in particular, notions of teachers' lack of 'technological fluency' in the literature have been ill-defined and over-generalised. Therefore, this study sought to gain a more nuanced view of the technological expertise that teachers in this setting bring to their classroom practice.

In order to address the above-mentioned learning design principles as part of a local problem, the project needed to draw on primary school teachers' expertise, domain knowledge and understanding of user requirements in the educational technology implementation design process. The presence of 'teachers' in the sub-questions, along with issues around their agency in relation to the overarching question of the potential offered by the educational service robot, indicates not only why it was necessary to create a collaboration between researcher and practitioners to solve the specific education research problem, but also why it was necessary to situate the problem in terms of a framework that theorises teachers' input.

Participatory design offers various contrasts with more traditionally qualitative education research, especially in relation to the extent that it may involve study participants in the actual design of the educational intervention. In education research with a more straightforwardly phenomenological focus, teachers' 'experience' as garnered in interviews is regarded as a source of data and analysed in terms of the meaning it brings to the text. While this meaning is understood to be open to further interpretation or reinterpretation, this is not routinely undertaken over the course of the project. In participatory design, on the other hand, and in much design-focused research into HCI in general, user input is treated as a requirement in the design process. In this sense participants' input is something that needs to be understood and then *acted on*, possibly in various different ways as the design is created, prototyped, evaluated and reiterated—often many times. Designers make sure that participants' input inheres over the course of the design process, even if the participants are no longer actively participating as designers. In this project, the teachers who contributed to the rich background knowledge and the drawing up of the design requirements for the educational intervention were therefore considered to be 'working with' the rest of the design and research team and are described in this way throughout the thesis. This was also partly the case because there was an expectation that they would be involved in the classroom evaluation stage of the implementation design. However, as noted, this phase was not reached in this study

Based on an understanding of participatory design, AR and DBR, this study chose to use DBR as its core research methodology. Because DBR allows different methods and approaches to be used at various stages within its iterations, participatory design was also used iteratively to involve teachers actively in the design process. AR was not followed for a number of reasons: because this research was not done individually; because the researcher was not a teacher; and because the goal of this research project was to involve researchers, education technologists, teachers and students working together on the introduction of the humanoid robot to the classroom.

Over the past decade, the Technological Pedagogical and Content Knowledge (TPACK) framework has emerged as a way of characterising the aspects of teachers' knowledge that are most relevant for technology intervention, so a decision was made to categorise, analyse and evaluate teachers' understanding of the problem space in terms of this framework. As noted in Chapter 2, TPACK refers to "the synthesised form of teachers' knowledge for the purpose of integrating ICT/educational technology into classrooms", especially in terms of teaching and learning practices (Mishra & Koehler, 2008). TPACK has three main elements: technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). CK represents the subject matter as it sits within the curriculum, while PK is associated with students' learning, teaching methods, learning theories, and principles of feedback and assessment needed to teach subject matter in the curricular context. TK refers to knowledge of how to use educational technology tools including software and hardware. TPACK as a whole conceptualises how teachers use various technologies to teach and/or facilitate knowledge creation in relation to specific subjects, content areas and topics.

Interview methods to establish requirements

This project used semi-formal interviews as a means for capturing teachers' input in the design process and for constructing guidelines for the creation of an evaluative learning activity designed to determine the potential scope and limitations of the proposed educational service robot. Chapter 4 describes this process in much greater detail; however, the following section describes the interview methodology that was followed and provides the rationale for using it.

Primary school teachers were recruited from four schools in Melbourne, Australia (see Chapter 4, Section 4.3 for details about these participants).Their input was collected through an online pre-interview questionnaire and then through interviews that used open, closed and scenario-based questions.

In HCI, interviews are used "in order to build an understanding of the needs, practices, concerns, preferences, and attitudes of the people who might interact with a current or future computer system” (Lazar, Feng & Hochheiser, 2010, p.180). Interviews are seen to have the potential to share people’s strengths, to involve a moderately large group of participants, and not to preclude gathering quantitative information. Interviews are “subjective and more open-ended, often providing deeper insights similar to those associated with ethnographies and case studies” (Lazar, Feng & Hochheiser, 2010, p.180).

Interviewing has been regarded as an effective method for documenting reflections from adults as participants in a study (Flannery & Bers, 2015), as this method has the ability to collect deep information, insightful thoughts, strong arguments and more detailed responses from participants – none of this is possible by ‘surveying'. Interviews can be open-ended and extremely flexible, where interviewers can have flexibility to re-order questions based on interviewee responses, and sometimes they can invent completely new questions linking to the responses (Lazar, Feng & Hochheiser, 2010).

Conducting interviews, however, is more difficult than providing surveys. Interviewers need significant skills for conducting interviews. It is hard work sitting with an interviewee for an hour or more, listening carefully to their responses, asking questions in the right order, taking notes, trying to decide which responses to pursue with further questions, using specialist knowledge to frame these further questions, and observing their non-verbal reactions.

Interviews work with small numbers of participants, where surveys can easily be sent to dozens/hundreds of potential participants who can complete them at a time suitable to them. Interviews on the other hand have a limit on the time available and require the presence of a researcher; if each interview is set for one hour, someone from the research team has to spend this time with the interviewee. If interviews take place at the interviewee’s place, research staff need to spend time to travel there. Another challenge of interviews is data analysis. It takes a great deal of time to transform raw notes into usable data, and transcribe audio recording to text format.

Interviews can be valuable for understanding user needs during the stage of gathering requirements because conducting interviews at the early stage of research is useful for understanding the users’ goals, their mental model for using available technology tools in the classroom, what they would like to do but can’t with the available resources, their frustrations, and their expectations. Conducting interviews in search of requirements involves considering an appropriately broad and open-ended view of possibilities where a focus on a narrow range of questions might limit the range of possibilities considered and answers given. The interviewer can demonstrate the artefact, mock-up or concept of initial design solution, discuss it with the participants and get their feedback. In this research, semi-structured interviews with individuals were used to interview primary school teachers in Melbourne, Australia about introducing humanoid robot technology into primary schools. The purpose of these interviews was to ascertain the teachers' TPACK knowledge, their experiences using existing educational technologies and their expectations of the use of the humanoid robot in their classroom. The interviews were also to lay the groundwork for developing an interaction paradigm that would support student learning using the humanoid robot.

Data collection

The data collected in this stage was qualitative data, the teachers' reflections on the use of the robot in their classroom. The teachers were asked to fill out a background questionnaire before the interviews. The interviews were recorded using an audio recorder and the researcher took notes.

Analysing interview data

The goal in analysing interview data was to produce an accurate representation of participants' responses and thoughts. The responses to individual questions were combined during analysis to build a picture of users' needs for a particular task, and their reactions to imaginary design scenarios, and to other issues addressed in the interview. This made it possible to find consistent patterns. Analysis becomes difficult when interview questions are more open-ended and unstructured since the open-ended questions can be answered differently by each participant. This project used NVivo software to identify and collate these kinds of discrepancies in the data and to prepare them for thematic analysis.

When data is collected using audio recording, the recordings document the complete responses of users and researchers can access this even months later to reconstruct detailed transcripts. The researcher in this project had the opportunity to analyse the recordings by listening to small segments at a time, repeatedly replaying interesting comments to gain better understanding. In addition, being able to return to the data became important when the prototype learning activity needed to be substantially redesigned in the later stages of the project (see Chapters 5 and 6).

The interviews were analysed through qualitative data analysis methods, which attempt to seek common patterns and themes from qualitative data. Content analysis is a common data analysis approach, where the text of the interviews is analysed for patterns of usage and then a structure is built from these patterns to identify what findings are important and why (Lazar, Feng & Hochheiser, 2010).

Codes and themes

A think-aloud approach was used for coding a transcript and also for developing multiple codes and themes. Developing themes from the data consists of noting important responses that answer the major research questions and following them up until an in-depth understanding of the central phenomenon emerges through thematic development (Creswell, 1999). We may identify 30 to 50 codes from initial data analysis and then it is possible to reduce these large numbers of "codes to five to seven major themes through the process of eliminating redundancies" (Creswell, 1999, p.248).

There are various types of themes:

- Ordinary themes: themes that a researcher might expect to find in the analysis process (directed).
- Unexpected themes: themes that are invented and not expected to surface during a study.
- Hard-to-classify themes: themes that contain multiple ideas and are difficult to fit into one theme or where several themes overlap.
- Major and minor themes: themes that in a database represent either the major ideas or the minor, secondary ideas of participants. The major themes can be used as meta-themes and the minors are useful for sub-themes.

Thematic analysis can be applied to analyse teachers' feedback on their experiences and expertise in using educational technologies and their expectations about using unfamiliar technology in the classroom. Audio and text data were analysed to identify classroom problem and the teachers' thoughts about possible solutions of using new technology in the classroom.

In this step, several methods were used to collect teachers' requirements for the use of robots in the classroom. The findings from this step helped the researchers understand the local classroom problems and possible solutions from a teacher's perspective. The next step sought a theoretical solution based on theoretical framework and design principles in the learning environment.

As Guest, MacQueen & Namey note, "Thematic analyses move beyond counting explicit words or phrases and focus on identifying and describing both implicit and explicit ideas within the data, that is, themes. Codes are then typically developed to represent the identified themes and applied or linked to raw data as summary markers for later analysis" (2014, p.9). Figure 4.3 shows the step-by-step process for data analysis and understanding the range of the qualitative data in this study (Bernard & Ryan, 1998). At first, interview data were divided into two types, audio and text. The audio data is then transcribed into text. In the next step, interview questions and transcriptions of interviews are reviewed to obtain a general sense of the material. Text is analysed as a proxy for experience in that it is assumed that individual teacher's attitudes, ideas, perceptions and experiences are represented in the transcripts. The transcripts-as-text are analysed using thematic analysis. From this high-level meta-themes are derived and these are systematically classified into sub-themes.

Figure 3.3: Understanding the range of qualitative data and the analysis process (adapted from Bernard & Ryan, 1998)

In terms of the thematic analysis the following methodological considerations need to be kept in mind. In qualitative research, credibility refers to whether a researcher accurately observed and documented what "participants think, feel and do". It represents both validity of measures and internal validity. To avoid bias in determining and elaborating themes, the researcher used triangulation by means of notes, audio-video recording during data collection and collegial checking. To enhance the accuracy of the interpretation of data, the researcher frequently referred to the users' voice, especially in terms of the participatory design with the teachers. Supervisors reviewed the audio recording to check the accuracy of transcripts and interpretations of interview data. The video data was also reviewed and the interpretations verified by the supervisors of this thesis.

Dependability refers to whether the researcher or someone in the research group keeps records of the processes and procedures of data collection and analysing data. In this thesis, detailed descriptions of sampling participants, recruitment process, materials, methods of data collection and analysis data were included in Chapters 3, 4 and 6. The supervisors also sample coded interview transcripts and observational data to reduce potential bias of a single researcher transcribing and analysing data.

3.2.3 Step 3: Development of solutions

After collecting the user requirements from teachers, the initial concept of curriculum alignment with the humanoid robot was designed in terms of teachers' reflections. In this stage, a learning environment was conceptualised that would perform the learning activity according to the requirements as collected. Recent literature on developing learning activities using educational technology tools was explored to validate this initial concept and to ensure that all possible ideas for curriculum design using robots were considered. Thus the initial skeleton of design was developed based on both a theoretical and practical understanding of the practitioners' design requirements. This initial design was generated as a potential solution to the identified problem. Constructing the initial design was important for the designers as it allowed them to identify the core features and to understand what kind of learning environment was being created. The designers then had the opportunity to make changes to the initial design and give reasons for these changes based on the evidence. Before considering the construction stage it is appropriate to introduce Agile methodology, which according to educational research has many advantages for early risk mitigation and customer satisfaction when constructing a prototype (Davey & Parker, 2010).

Agile methods

Pressman (2010) defines Agile methods as "A philosophy and set of development guidelines. The philosophy encourages customer satisfaction and early incremental delivery of software … the development guidelines stress delivery over analysis and design" (cited in Davey & Parker, 2010, p. 298). There are three reasons why the Agile method is useful for software development projects in education (Davey & Parker, 2010).

- Software requirements are not predictable because they can change over time as the project proceeds.

- Design and construction are closely linked in many software projects; there are often forced changes to software design during construction because of difficulties in the implementation stage.
- Design concept, construction, and evaluation outcomes are not predictable.

The Agile Alliance (Alliance, 2009) proposes a set of principles for constructing a prototype, which were adapted for use in this software development project as follows:

- Satisfy the practitioners, who are the clients of this project, by involving them in the design process from an early stage.
- Be flexible about changing requirements, if necessary even late in the development stage.
- Work closely with the practitioners in all stages of this project
- The most effective method of collecting information is face-to-face conversation, and this will be used to collect requirements from teachers.
- The primary measure of progress is a working prototype
- Use agile processes to support development.
- Pay continuous attention to technical challenges during the construction stage
- The prototype design should have 'simplicity'
- The researcher/ design team must reflect at regular intervals on how to become more effective and then adjust their behaviour accordingly.

The skeleton or initial design for the learning activities was developed based on the TPACK framework, using the teachers' requirements (see Step 2 above for how these requirements were generated). The skeleton design also indicated the scope of the project, defined primarily in terms of goals, users, time and budget. Linking the goal to specific components in the design helped establish and maintain focus. The users were the researchers, experts, developers, and designers, who were, directly or indirectly, involved in creating or implementing the design.

After the skeleton or initial design, a more detailed description of the design solution to develop learning activities was documented, again based on TPACK and the teachers' requirements from Step 2. Learning activities are a set of activities, which fit the curriculum and support pedagogy in the classroom. These activities around the use of a humanoid robot to support literacy/numeracy/technology project/programming language/positional language learning were developed based on feedback from teachers as to how they would like to use these activities with their students.

The educational researcher worked closely with teachers to identify curriculum activities suitable for the use of a humanoid robot, and ways that children might learn with the robot. Questions considered include:

- Which learning activities within Australian government curriculum guidelines can use robotic educational technologies?
- Is student learning with the robot better facilitated within a group or individually?
- What kind of students will benefit more from the robot?
- How can this robot be best used - as a teacher's assistant? a learner aide? an educational tool?

3.2.4 Step 4: Construction - Iterative cycles

DBR supports multiple iterations involving researchers, practitioners and developers in the design process. Using DBR methodology it is not expected that a satisfactory research outcome will be reached after just one iteration. For this project, three iterations were planned initially to fit the time limits of a Ph.D. project. Multiple iteration followed the steps of: initial concept development, construction, in which initial prototype was constructed involving participants, data collection, data analysis, and outcomes.

Iteration 1: Prototype developed

This section focused on how to construct a learning activity and what skills and effort were required to develop an activity that met the teachers' requirements.

A prototype learning activity was developed in this stage by the development team.

There are various types of prototypes in educational technology design research; examples are: "semi-functional, documentation or memo, guidebook for teachers to prepare a lesson plan, and preparing agenda" (Cooper, 2004). The range of prototypes runs from initial to complete, and, as is common in technology based interventions, the functionalities increase over time as the product evolves from temporary to final version, (Cooper, 2004). Stages can be defined as:

- Mock-up: the initial stage of design; few components have been elaborated.
- Semi-functional: the partial design stage with several components developed.
- Fully- functional: all components are developed and fully working.

Participants

The educational researcher worked with a software development team, who had experience in the programming needed to make a robot interactive. The Agile method was used for regular communication between the researcher and the team. The researcher, who developed the concept for the learning activity, acted in the role of client in this stage. The team met the client each week to receive feedback on their deliverables from that week.

Method

Design scenarios based on teachers' reflections from Step 2 were used to understand the pedagogical context and student-robot interactions within the learning activity.

In this study, interaction-based design scenarios were developed to understand the functionality of the prototype for the learning activity and how students and practitioners would interact with the robot during the activity. This method is useful when creating a narrative explanation for interactions between the design/tool and the end users. Scenarios are used in technology integration design to engage teachers in the design process of technology enhanced learning. Scenarios support designers in imagining situations before they occur and these form the basis for user narratives, which describe specific situations, invite users to reflect on situations based on individual perspectives, and allow open discussion of their expectation of using the technology (Carroll, 2000).

Goals from this step were:

- Successful implementation of a fully-functional prototype for the learning activity
- Interaction design in terms of student-robot interactions using the activity
- Alignment of the learning activity with the Australian curriculum
- Observing any challenges to implementation
- Identification of the degree of programming knowledge and the amount of preparation time required from teachers. This iteration continued until the successful implementation of the prototype, and challenges encountered were recorded as they arose.

Iteration 2: Prototype tested with children

After successful implementation of the learning activity using the humanoid robot by the development team, the activity was tested with primary aged children to observe the impact on their learning progress.

Participants

Primary aged children from various schools in Melbourne, Australia were the participants at this point in the study. They interacted with the learning activity and the researcher observed their learning progress. Children participating were from foundation year to grade 6, both male and female, and with varying degrees of experienced/inexperience in programming languages.

Method

The main method used here for the collection and analysis of data was observational study (Lazar, Feng & Hochheiser, 2010). Observational study involves the systematic detailed observation of behaviour and talk; for example watching and recording what students say and do. Observational studies follow a phenomenological approach: the researcher focuses on study participants' experience, trying to capture an account of this from their own perspective (Bryman, 2001). The internal-external observation method was used during testing (Miyake, Miyagawa, & Tamura, 1998), where the observer encouraged the child to talk during the free play activity but did not take part in the activity itself although the observer did direct them in some points.

Video was chosen as an appropriate data collection method for the observational study. It allowed children/teachers/researcher to show the robot and its programs in action, and made it easy for teachers and researchers to record the interactions between children and robot more completely than audio recording or still photographs could have done.

In general video recordings are a useful data collection method for the systematic understanding of entire activities and for observing students' behavior, especially their gestures and facial expressions. Video format data goes well with material driven activity, and it is particularly effective when the data analysis and the evaluative process take place at a later date. Video footage gives context to conversations between researcher and participants, and makes it possible to see exactly what the participants are working on or how they are using a technology tool.

Video documentations record students' verbal and non-verbal communication and also their body language and facial expression, all part of observing their experiences and learning process. This method is also useful for shy students who can be expressive but not verbally articulate.

In summary video is an ideal tool for documenting technology use and non-verbal behavior of children, which is the reason why this project chose to video the children as they were testing the learning activities.

The observation was captured across three areas: children and their facial expressions and body language; the screen contents when they worked on a laptop; and their use of physical materials and resources, for example cards, laptop and robot. It was not possible to use one camera to capture all three different areas so a digital video camera was used for recording the children's behavior and the context of use, and Camtasia software was used for capturing the screen content when they were working on a laptop.

Video recordings were collated and the children's behavior in the learning activity session was coded in terms of the pedagogical framework of computational practice (see Chapter 6, section 6.3 for full details). Children or their parents were also asked to complete a questionnaire to provide demographic data and supplementary information regarding age/grade, gender, experience with technology and how much time they had spent on the use of various technologies at home/school. After the observational study in a controlled environment, it was planned that the next iteration would be conducted in a real classroom with both teachers and students using the learning activity based on the humanoid robot. However, this iteration was not achieved in this project (see Chapter 7).

3.3 Conclusion

DBR methodology was used in this research project because of the nature of the study although the researcher is aware that this methodology has its limitations. This research took into account the most important characteristics of DBR as compared with other educational research methodologies, and made the decision to use DBR as the methodology for this project.

Figure 3.4, below, illustrates this project's design process following the DBR methodology:

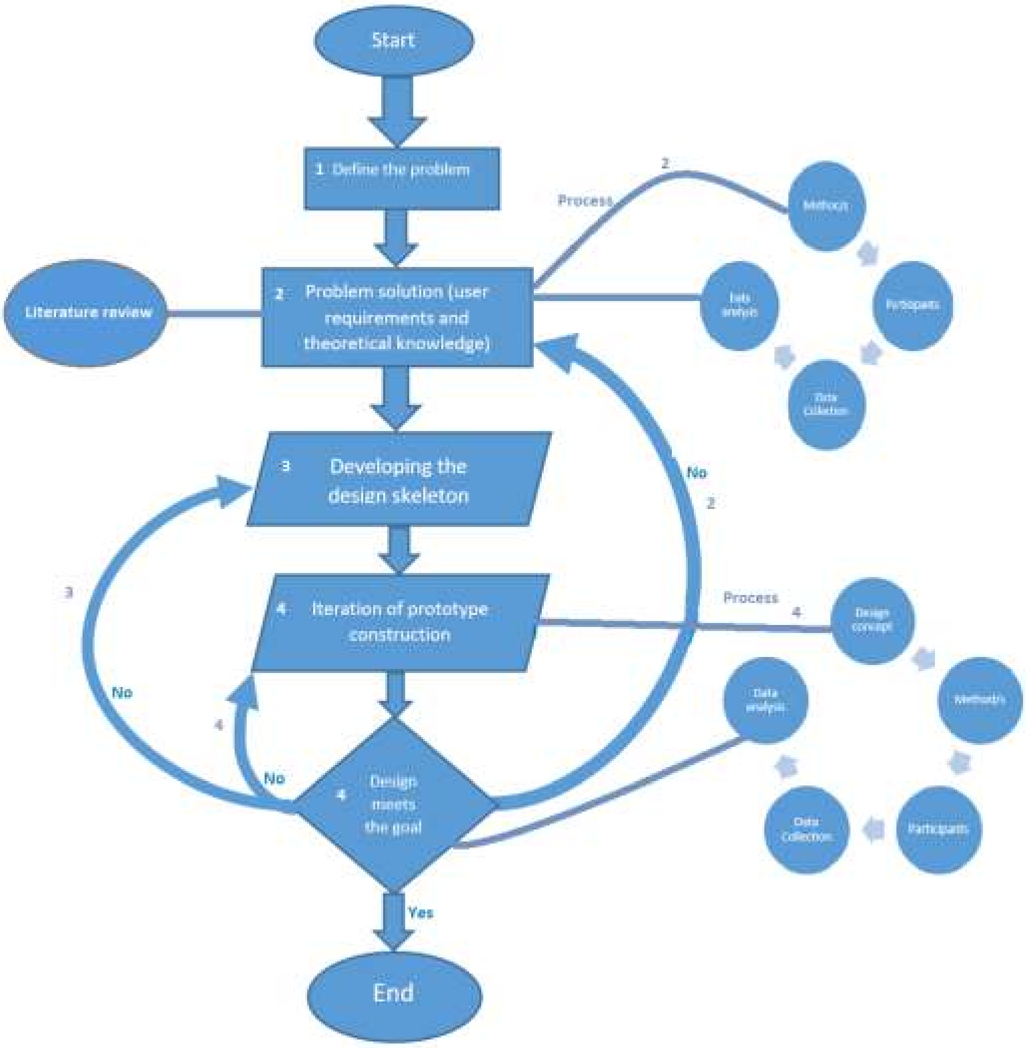


Figure 3.4: the detailed steps of DBR

Figure 3.4, showing the detailed steps of DBR followed in this project.

Step 1: The process started from a literature review to identify a gap or problem when integrating humanoid robots into the classroom of a primary school. Based on this review, the main and sub-research problem was identified in the Chapter 2.

Step 2: The next step identified a possible solution to the specific problem based on theoretical and practical knowledge. In this step, practitioners worked closely with the researcher to provide their TPACK knowledge. Interviews, questionnaires and scenarios were used as the methods for gathering user requirements from teachers, and then their feedback was analysed using thematic analysis.

Step 3: Based on the teacher’s reflections and revealed requirements, a learning activity was designed and developed in the next step to evaluate the robot's potential contribution.

Step 4: This learning activity was implemented as a functional prototype by the development team based on the research (Step 4, iteration 1 in Table 3.1). This iteration continued until implementation of a successful functional prototype using the stages of method, participants, data collection and analysis. After successful implementation of the prototype, the next iteration (Step 4, iteration 2 in Table 3.1) involved testing the learning activities with children in an experimental environment. If the outcomes of the test had been as expected, the research would have moved to the next step which was testing in the classroom (Step 4, iteration 3 in Table 3.1), otherwise the project would iterate through the previous steps (2/3/4) depending on the nature of the outcomes. When the design met the goal or achieved successful outcomes in the classroom environment, the DBR process would be at an end.

The next chapter will describe the second step in the DBR project, as the first step has been discussed already in Chapter 2.

4 Teachers' input

This chapter describes the phase of the project that engaged teachers in the early design process. Information was gathered from primary school teachers in Melbourne, Australia, using a questionnaire and interviews in order to synthesise the initial design requirements. The overall aim of this thesis was to answer the central question: *How can implementation design be optimised for the successful implementation of educational service robots in primary classrooms?* Answering this question led to a focus on using design based research (DBR) to incorporate teachers' technological pedagogical content knowledge (TPACK) into the design process to create a learning activity that would help to evaluate the robot's potential.

Chapters 2 and 3, above, discussed the theoretical background to this, including the literature, and explained the choice and dynamics of DBR (Flannery & Bers, 2015). DBR is an emerging approach, which seeks to guide technology interventions in 'localised' educational settings and involves prototyping and multiple iterations (Anderson & Shattuck, 2012). Chapter 2 also reviewed the literature on TPACK and various educational technologies. It discussed research into educational technologies over the past 15 years, and justified the choice of a humanoid educational service robot as the technology selected for this study.

The current chapter provides findings based on the participating teachers' TPACK which was used to inform stages of the integration design process (described later in Chapters 5 and 6). It first presents an introduction and overview in Sections 1 and 2. This is followed in Sections 3 and 4 by the details of the study design for gathering local input from primary school teachers. Results from the teachers' questionnaire are presented in Section 3 as participant profiles. Results from the interviews with teachers (as well as some of the open questions from the questionnaire) are presented and thematically analysed in Section 5, and discussion of the whole follows in Section 6.

4.1 Introduction

The advent of humanoid robots is an exciting development that allows for increasingly naturalistic interaction between humans and technology. This project aims to improve design processes for implementing new education technology, such as educational service robots, into teachers' classroom practice. It also contributes to an emerging interaction paradigm that will support student learning using humanoid robots (Magyar et al., 2014).Implementation design of education technology means considering how the technology will be used by teachers within schools. There is a wide range of factors to consider when offering an unfamiliar technology to a school. Some of these factors are reliant on teachers' and students' acceptance and teachers' knowledge of learning-centred pedagogies such as constructivist learning design (Clements and Sarama, 2002; Magyar et al., 2014). The importance of more pragmatic factors such as training and resources has also been demonstrated (Clements and Sarama 2003, Magyar et al. 2014). As noted in Chapter 2, recent research into the potential of humanoid educational service robots has focused on the need to ground implementation design in actual classroom practice and to bring teachers into the design process (Serholt et al., 2016). As well as providing user-knowledge of education technology, teachers can offer expertise in pedagogical aspects of the use of technology for learning in classrooms (Mishra & Koehler, 2006). Capturing this knowledge and using it in controlled research and observation (Flannery & Beers, 2015) before deployment of education technology will help to minimise the risk of 'technology-enhanced non-learning' (Bunz, 2016). It will also obtain richer data to further inform teaching and learning strategies related to technology implementation.

This project used the framework 'Technological Pedagogical Content Knowledge *(*TPACK)' to integrate how a group of teachers would make use of robotic technologies to teach and/or facilitate knowledge creation in this context.

Research on the use of robots in education suggests that 'robots will become more and more part of classroom activities around the world' (Reich-Stiebert & Eyssel, 2016, p. 671). However, research on robotics in primary education is still uncommon (Reich-Stiebert & Eyssel, 2016). To date most studies have focused on students' attitudes towards robots in school/education contexts, and some have considered primary school teachers' acceptance of educational robots (Fridin & Belokopytov, 2014). Recent studies argue that in addition to gauging acceptance from teachers as 'gate-keepers', it is necessary to engage teachers in optimisation of the implementation process before the technology is introduced into practice as this will reduce the gap between technology and end-users (Serholt et al., 2016; Reich- Stiebert & Eyssel, 2016). Researchers now recognise the importance of involving teachers as participants in the design of technology-enhanced learning (Matuk et al., 2016). To this end, the main research question for this chapter became: *How can teachers and researchers work together to optimise the implementation design for the introduction of a humanoid service robot into a primary school classroom?* Stemming from the notions of user-centred and learner-centred design (Soloway, Guzdial, & Hay, 1994), a participatory design approach ensured that design decisions were informed by teachers' needs and experiences (Matuk et al., 2016). Chapter 6 of this thesis goes on to consider how the design can also be informed by children as end-users.

4.2 Study overview

Qualitative methodology was used in this part of the project to explore the complex factors related to primary school teachers' perspectives on integrating new education technology. Six teachers were recruited for the teachers' input phase, which took place in 2015. Using a detailed questionnaire, the study initially focused on understanding the teachers' local teaching environments and establishing their current use of technology in their classroom and their views on the capacity of technology to enhance learning. Then, by interviewing the teachers, the investigation sought to ascertain their perspectives on the *potential use, benefits and challenges* of incorporating a humanoid teaching robot into their classroom practice.

Participant profiles were drawn up (Section 3, below) and data from the interviews and open-ended questionnaire questions were thematically analysed (Section 5, below). In line with DBR methodology, conclusions and provisional recommendations arising from the analysis informed the development of the later phases of the overall project (see Chapters 5 and 6), including the final phase (Chapter 6) where students engaged with the humanoid robot for the acquisition of learning through exploration and reflection. The teachers' input was essential to ensure that there was a clear understanding of the themes and variables arising from the teaching context that might affect the implementation design.

Ethics approval and recruitment

Ethics approval was sought from Swinburne University of Technology and the relevant education body (the Catholic Education Office, Melbourne) to conduct this part of the study, which involved recruiting, surveying and interviewing primary school teachers in Melbourne, Australia. Approval was granted on 6 November 2014 [SHR Project 2014/154]. Four schools were targeted in Melbourne based on random selection and request letters were sent to their principals. After receiving permission from the principals of the four schools, teachers from these schools were invited to participate via email. Email addresses of teachers were also collected from the school principals and posters were placed on the staff notice boards. The letter of request to the principal, the email invitation to teachers and the poster are given in Appendix A. Expressions of interest from responding teachers were pursued and participants were screened to ensure a broad spectrum across the required background in order to provide a non-biased sample. Data was collected by means of a background questionnaire, observations and interviews.

Study procedures

- Step 1: Primary school teachers were invited to participate in the study. Six teachers confirmed their willingness to participate. Participants were informed that participation in the interview was voluntary and participants would not be identified in any subsequently published results. They were also notified that they could access support via email, telephone calls and/or visits by researchers to the school during the study.
- Step 2: Participants informed the researcher of a suitable time and location for the interviews.
- Step 3: Participants were invited to complete a background questionnaire via a link to Opinio, which is a secure web-based survey application, before participating in the face-to-face interviews (see a list of the questionnaire questions below, in Table 4.1).
- Step 4: One-hour interviews were conducted at the teachers' schools. During them, audio recordings were made with a digital recorder and hand-written notes were taken by the researcher, both with the consent of the participants. In the interviews the teachers were first asked to watch a video about the use of a teaching robot in classrooms (see description of the video in Section 4, below). Then they were asked a range of both directed and open- ended questions about the potential use, benefits and challenges of the teaching robot in their classrooms (see list of interview questions below, Table 4.2).
- Step 5: Information given by teachers in the questionnaires and interviews was collated and analysed, as described below in Section 4. Data was separated from the consent form to enable anonymity and was securely stored by the researcher.

4.3 Background online questionnaire study and participant profiles

As noted above, six teachers across four primary schools in Melbourne participated in this study. Four of them were between 25 and 39 years of age, one was 39 and the other more than 50 years old. These three female and three male teachers had been involved in education for varying periods between two years and longer than five years; one had 27 years of experience in education. They had acted in the role of classroom teacher, administrator (1), and team leader (3). They had also held specialised roles as: digital learning leader, OHS rep for staff, parental club officer, inquiry officer for a curriculum team, and member of the inductions committee.

Schools were chosen where the teachers had no prior experience of using a humanoid education service robot in the classroom. However, to contribute to the project the teachers had to have some degree of knowledge about using technology tools for education purposes. This meant that the schools needed to be able to invest budget in technology and to assign technical support for this technology. The schools were all located in the eastern and outer eastern suburbs of Melbourne, where the socio-economic status in terms family income tends to be higher, according to ABS census 2006. Schools in these areas may have the opportunity to access better technology-related facilities and services than in other parts of Melbourne.

Participant's code	Gender	Schools	Type of school
John	Male	D	Private
Frank	Male	A	Public
Jannie	Female	D	Private
Steve	Male	C	Private/Catholic
Sarah	Female	B	Public
Tina	Female	A	Public

An online questionnaire was used to elicit responses to both closed and open questions designed to give a broad and detailed idea of the teachers' experiences of education technology. After recruitment, a link to the background questionnaire was provided via email. Study participants were first asked to give their gender, age, school, educational role, what grades they taught, and any specialist subjects. They were later asked about their current use of technology in the classroom (see Table 4.1, below, for the full set of questions).

Questions	Type of questions
Question 1: Name	Background/closed questions
Question 2: Gender	Background/closed questions
Question 3: Age	Background/closed questions
Question 4: School	Background/closed questions
Question 5: How long have you been involved in education?	Background/closed questions
Question 6: What are the roles have you filled over that time in the primary school?	Background/closed questions
Question 7: Main activities in 2015	Background/closed questions
Question 8: Does your school have a technology policy?	Background/closed questions
Question 9: Do you feel your school encourages you to use technology by providing the following or other assistance? • Time allowance to learn about new technology • Time allowance for preparation to incorporate new technology • Budget for equipment • Budget for training • Expert to assist with technical requirements • Expert to assist with incorporating technology into educational activities	Background/closed questions
Question 10: This question is about the technology that is available to you. You may use this technology at home, at work or with the students.	Background/closed questions
Question 11: When your students use a technology tool, do they do so in groups or individually?	Background/ closed questions
Question 12: If you do use technology in the classroom can you describe some examples including the subject, the technology, how the technology is used, how successful is the use of the technology compared to traditional teaching methods.	Background/open questions
Question 13: For the technology you have identified that you use with the students, what is your main reason for using these? • It is an expectation by the school • I find it useful for effective teaching • I find it encourages students to be involved	Background/closed questions
Question 14: What benefits (if any) do you see using (computer) technology in your classroom? Examples:	Background/open questions
Question 15: Do you have any difficulties with using (computer) technology in your classroom? • problems with quality of technology • availability of technology	Background/closed questions
• Other	
Question 16: How would you rate how you feel about using technology for teaching? • Not enthusiastic vs enthusiastic (very unlikely 1 2 3 4 5 very likely) • No interest vs interest of using new technology (very unlikely 1 2 3 4 5 very likely)	Background/closed questions
Question 17: Do you have a dream scenario of how you could use technology to enhance student learning in the classroom?	Background/open questions
Question 18: Is there anything else you would like to add regarding using technology in the classroom	Background/open questions

Table 4.1: The background online questionnaire

Questions 5-7 related to the main activities the teachers were doing and their roles in them over the past year. In Question 7 they were asked what topics they had taught recently and what kinds of things they did to get key concepts across to their students. They were invited to write about their teaching sessions and their use of technology tools. These questions were designed to help the teachers think about a specific instance to focus on, making it easier for them to recall details of what they did. Questions 8 and 9 asked about technology policy in the teachers' schools, and how their schools encouraged their teachers to use technology tools in the classroom. They were asked in Question 10 about time spent teaching students using technology and how they gauge the appropriateness of education technologies for different learner types. The teachers also wrote in Questions 11 and 14 about the main reasons for and benefits of using technology with students and their future expectations about using technology in their classrooms. In Question 15 they were asked what technology tools they used, and whether they or students had found any difficulties using them.

The purpose of asking these questions was to collect information on:

- Use of technology tools for learning activities in the classroom and any difficulties using them
- Use of technology with students: one on one, or in groups
- Use of teaching strategies (constructivist, rote, role playing, etc.)
- Use of different strategies for different students (learning styles)
- Why the techniques/tools were accepted or rejected (e.g., they weren't working, too difficult or fiddly to do, not enough time to do, problems with tools/technology, teaching students to use the tool was time consuming)
- Problems with meeting or matching learning outcomes and with quality of technology

Study participant profiles are given below, based on background data from the individual teacher's responses to the questionnaire.

Participant 1

John is a male primary school teacher between 30 and 39 years old, with more than five years of experience of classroom teaching from Grades 1 to 6. He has also acted in the roles of specialty subject teaching, administration and leadership. He is experienced in using technology and is very enthusiastic about and interested in using new technology. He considers himself very well prepared to use technology in the classroom. He regards technology as a medium that he finds easy to learn about and use.

John spent 15 to 19 hours at home, more than 20 hours personally at work, and one to five hours with students for lessons in the classroom, using computers, per week. He spent time on an iPad each week: 1 to 5 hours at home, 6 to 9 hours personally at work, and 1 to 5 hours with students in the classroom. Using an interactive whiteboard, he spent more than an hour a week personally at work and with students for lessons. He also used robotics and circuits to teach students computational thinking and each week spent one to five hours personally and nearly an hour with students teaching with this in the classroom.

John used iPad, Apple TV, and iMac in all subjects. He used Makey Makey to allow students to invent and problem solve. He also used programming applications like Hopscotch and Tynker to develop computational thinking and to enable students to understand the inner workings of machines, robots, and computer applications. Students used technology in groups. The learning tasks are designed for collaboration and so the technology just acted as a personal tool to enable contribution.

John noted the learning tasks were designed for collaboration and so the technology acts as a personal tool to enable contribution. Technology tools support student entrepreneurship and empower them to take social, moral and educational action.

His school had a technology policy and the school encouraged him to use technology by providing a time allowance for preparing to incorporate new technology, a budget for equipment and training, and an expert to assist with technical requirements and incorporating technology into educational activities. His main reasons for using technology with students were: it was an expectation by the school; he found it useful for effective teaching; and it encouraged students to be involved.

Participant 2

Frank is a male primary school teacher, between 30 and 39 years old with five years of experience as a classroom teacher of Grades 3 and 5, and also specialist subject teaching. He is very enthusiastic, interested in using new technology, and moderately well prepared to use any technology.

Frank wrote about the technology policy in his school, noting, “not specifically but there is a general consensus towards using technology”. His school encouraged him to use technology by providing a time allowance for preparing to incorporate new technology and budget for equipment, and an expert to assist with technical requirements.

Frank spends between 1 to 5 hours on a computer at home, 1 to 5 hours personally at work, and 1 to 5 hours with students for lessons in the classroom per week. He spent time on an iPad per week: 6 to 9 hours at home, 1 to 5 hours personally at work, and 1 to 5 hours with students in the classroom.

Frank used iPads, Apple TV, and iMovie in his classroom. Students used iPads both individually and in groups. He also liked students to share ideas and skills with one another so they can learn from their peers.

The school had just introduced iPads to the year 5/6 levels to help incorporate ICT into their learning. Throughout the year levels computers and iPads were available and used daily. Students used iPads both individually and in groups. He also liked students to share ideas and skills with one another so they can learn from their peers.

Frank noted students used iPads for research and they used it to create TV advertisements. The students used iMovie and loved using the technology to create something they hadn't done before. The students were proud of their work and they all learnt new skills. As a teacher, he was always encouraging students to explore using ICT to help them learn further.

He mentioned the main reasons for using technology with students. He identified it was useful for effective teaching, and it encouraged students to be involved. He also found it opened up another creative outlet that they might have.

He experienced difficulty in using technology in the classroom because of availability of technology tools. Often there were not enough computers to go around for all students. Occasionally he was not very familiar with a program, but he normally made sure he ‘had a play around with it’ before he introduced it to students.

Participant 3

Jannie is a female primary school teacher of less than 25 years age, with two years of experience as a classroom teacher from Prep to Grade 6, as well as experience in leadership and administration. She is enthusiastic and interested in using any technologies but not so well prepared to use it.

Jannie noted the technologies available to her, and how much time she spent on using these technologies per week. Per week she spent 15 to 19 hours at home using a computer, more than 20 hours personally at work, and 6 to 9 hours with student for lessons. She used an iPad between 10 to 14 hours a week at home, 15 to 19 hours at work, and 1 to 5 hours with students for lesson. She also used an interactive whiteboard around 6 to 9 hours per week at work and with students for lessons.

Students used one on one iPad programs in Grades 5 and 6, and a class set of iPad minis were sharing amongst year levels. Apple TVs and an interactive whiteboard were in use in the classroom daily. Sometimes she had difficulties of using these tools because of the quality of technology.

The main reason she gave for using these technologies in the classroom was because it was an expectation by the school. She mentioned her school had a technology policy and encouraged her to use technology by providing time for preparing to incorporate new technology and a budget for training.

Participant 4

Steve is a male primary school teacher, between 30 and 39 years old, with more than five years of experience as a classroom teacher of Grades 4 and 6 and as a technology leader. He is very enthusiastic about using technology for teaching.

Steve noted that there was a technology policy in his school. His school encouraged him to use technology by providing time for preparing to incorporate new technology, a budget for equipment and training, and an expert to assist with technical requirements.

Steve noted the technologies available to him, and how much time he spent on using these technologies per week. For using a computer, he spent between 15 to 20 hours at home, more than twenty hours personally at work, and 1 to 5 hours with students for lessons in the classroom per week. He spent time on an iPad: 6 to 9 hours per week at home, 1 to 5 hours personally at work, and 1 to 5 hours with students in the classroom.

He mentioned the main reasons for using technology with students. He identified it was an expectation of the school, useful for effective teaching, and that it encouraged students to be involved. He found difficulty in using technology in the classroom because of lack of availability of technology tools.

Participant 5

Sarah is a female primary school teacher, 25 to 29 years old, with more than five years of experience as a classroom teacher from Prep to Grade 3, and as a digital leader. She is enthusiastic about using technology in the classroom.

Per week Sarah spends between 1 to 5 hours at home using a computer and 6 to 9 hours personally at work. She used an iPad 6 to 9 hours per week at home, 1 to 5 hours personally at work, and 1 to 5 hours with students in the classroom.

Sarah used iPads, Apple TV, Smart board and a wireless colour printer in the classroom. Her students used iPads in pairs and students were highly engaged. The iPads make it quick/easy for the teacher to resource the lesson.

She used iPads for videoing role plays where the children practised their social and oral language skills. Sarah took photos of the children in the playground using iPads for demonstrating positional and directional language concepts. She used Smartboard software to model concepts like ten frames and addition/subtraction software. She used interactive websites on the Smartboard.

Sarah wrote about the technology policy in school, and she noted, "The school does not have a technology policy, but there is general consensus towards using technology". She mentioned that her school encouraged her to use technology by providing a budget for equipment, an expert to assist with technical requirements and with incorporating technology into educational activities.

She noted about the limitations of resources for each child, "We used iPads with a partner because they did not have enough devices for each child". She reported having problems with the quality of technology, technical difficulties, and availability of technology in the classroom.

Participant 6

Tina is a female primary school teacher more than 50 years old, who has twenty-seven years of experience in education as a classroom teacher from Prep to Grade 5, and in leadership. She is enthusiastic, interested in using new technology, but not so well prepared to use technology in the classroom.

Tina spent less than an hour personally at work using a computer and between 6 to 9 hours with students for lessons per week. Each week she used an iPad an hour personally at work, and 1 to 5 hours with students in the classroom, and less than an hour for the interactive whiteboard.

Her students used iPads, Apple Macs either individually or in groups or even at times in pairs depending on the task.

Writing about the technology policy in school,she noted, “not specifically but there is a general consensus towards using technology”. The school encouraged her to use technology by providing a budget for equipment, and an expert to assist with technical requirements. However, she felt her school needed a lot more ICT equipment and training. She also mentioned, “It would be nice to have an expert to assist with incorporating technology into the classroom”. She would like time set aside to play with new technology, but she did not usually receive this.

As the main reason for using technology with students she noted that using technology encouraged students to be involved. Sometimes she had difficulties using these tools because of the quality of the technology, availability of technology, and personal knowledge about how to use the technology.

After collecting the teachers’ background data, semi-structured interviews were conducted. These are described in the next section.

4.4 Semi-structured interviews study design

In the second part of the teachers’ input study, individual one-hour interviews were conducted with each of the six teachers. At the start of each interview, the teacher was invited to watch a short video (around 11 minutes and 20 seconds) about a series of proposed educational uses for the NAO humanoid robot.

The video was made by researchers whose aim is to demonstrate the potential of the humanoid robot in the classroom and show how this robot could help to engage students. The aim of showing this video was to help teachers visualise the hypothetical use of a humanoid robot in their classrooms, and to give them ideas about how they might incorporate it into their teaching practice. The video gives ideas about how children might interact with a humanoid teaching robot and their various levels of acceptance of it.

There are four parts to the whole video that was shown to each study participant:

- The first part of the video shows developers, animators, and researchers using a humanoid teaching robot in special education to enable children’s learning.

- The second part shows the teaching robot being used in primary and secondary schools in the

  U.K. Initially, children are confused about what this robot can do. However they also have fun watching the robot being used for programming and animation. Their teachers suggest that it could be useful for science, engineering and computer science. Students in the video also work in a class on Shakespeare using the robot, making pictures and programming it to see the picture and give a speech.

- The third part shows educators using the same teaching robot to explain to students the importance of nutrition and physical education, and notes that this is a new way to inspire students to become health conscious.
- The fourth part shows how the robot could be used for language learning with primary school children. Children are shown teaching the robot themselves and in this way their understanding of the subject matter, and consequently their own learning, is improved. This part of the video gives a method for language learning in the classroom and shows the children's acceptance of the robot for this purpose.

Overall the video shows that the humanoid robot has the capabilities to act as a learner, a teacher's assistant, or a research assistant.

Semi-structured interviews were then conducted with each teacher, with ten questions providing an initial guideline for structuring the interview session are shown in Table 4.2. The teachers were also encouraged to discuss their own education technology experiences and their attitudes to the potential use of the humanoid teaching robot in the classroom. A response to one question sometimes raised other questions. The predefined questions acted as a guide to make sure similar ground was covered in each interview. The aim of the interview process was to gather information about:

- The acceptability of this unfamiliar technology for use in the classroom (i.e. acceptable to themselves and their students)
- How the technology might best be used in the classroom for engaging students in their learning
- How it might achieve better learning outcomes
- Teachers' pedagogical suggestions on the process to integrate a humanoid robot into the classroom
-

Questions	Type of questions
Imagine you had a teaching robot in your classroom and we could program it to do anything you wanted it to do? What would be your dream scenario about how you could use the robot in your classroom?	Imaginary scenario / open question
How could it fit in – what tasks could it do? What would be your nightmare scenario?	Imaginary scenario/ open questions
Do you think the robot would engage students? Why?	Open questions
How could you use this technology as a group or individually?	Open questions
Do you think that it is something where the novelty would wear off	Open questions
Do you think the robot would work better for some students than others? Why?	Open questions
What contributions do you think the robot could make to your classroom? Could it be used as a learner rather than as a teacher?	Open questions
What skills do you think a student could gain from using a teaching robot?	Open question
Is there anything else you would like to add?	Open question
Let's pretend you got a new job and your boss said to you 'Alright, here's a robot for your teaching', what would be the first things to go through your head?	Imaginary scenario

Table 4.2: The semi-structured interview questions

The individual interviews were conducted in each teacher's classroom, so it was a familiar environment for them. Teachers had been scheduled for one-hour interviews at times that suited their availability. Interviews were recorded by an audio device and afterwards the audiotaped data was transcribed and reviewed. The analysis was ongoing throughout the study and each phase of data collection was shaped by prior data.

Later, data from the interviews and from written responses to the open questions was more thoroughly analysed using NVivo software. During this process it was coded in terms of both the interview question schema and what the teachers emphasised most frequently about the potential use of the humanoid teaching robot in the classroom.

4.5 Meta-themes and sub-themes - outline

The meta-themes in this study were derived from a combination of the interview question schema and the most common frequencies of teachers' stated ideas around how they would integrate the humanoid teaching robot into their classroom.

During interviews, teachers were asked questions around three main topics:

- how they would use the robot
- what benefits it could offer
- what challenges it might bring

These questions could be open-ended (OE), directed (D) or involving explicitly named scenarios (S).

Scenarios are used in technology integration design to engage teachers in the design process of technology enhanced learning. Scenarios help teachers to imagine a situation before it occurs and to create user narratives which describe specific situations. These invite users to imagine and reflect on situations based on their individual perspective, and encourage open discussion of their expectations from using technology (Carroll, 2000). During the interviews, the teachers were asked to react to imaginary scenarios where they might use a humanoid robot in their classroom, and to envision what would be the challenges and benefits of integrating this robot into the classroom (Matuk et al., 2016).

Questions around potential 'use' were:

- *How would you use the robot with students in the classroom? (OE)*
- *Would you use this technology as a group or individually? (D)*
- *Would you use it as a learner rather than as a teacher? (D)*
- *How could this robot fit into your classroom? What tasks could it do? (OE)*

These kinds of questions were seeking to establish what types of teaching and learning practices would be supported by this technology. Teachers were asked about the possible tasks or activities students could do with the robot and how they might be able to use this robot to enhance active student participation in the classroom. Directed questions asked whether students could use this robot in group situations or individually. Teachers were also asked about possible roles for the robot as a teacher's assistant or learner in order to draw out teachers' ideas about possible teaching methods that would encourage students' interaction with the robot in their classrooms.

Questions around potential 'benefit' were:

- *What would your dream scenario be for using the robot? (S)*
- *Do you think the robot would engage students? Why? (D)*
- *What contributions do you think the robot could make to your classroom? (OE)*
- *What skills do you think a student could gain from using a teaching robot? (OE)*
- *Do you think the robot would work better for some students than others? Why? (OE)*

These kinds of questions were asked to understand both teachers' and students' attitudes to and acceptance of the humanoid teaching robot. Teachers were also implicitly asked to reflect on how students might benefit from using this robot in their learning, what types of learners would learn better with this robot, what skills students could gain with it and whether they could achieve better learning outcomes. This robot has the ability to interact with students socially. So it was hoped that teachers would share their thoughts on whether students might be encouraged to use this robot for socially interactive activities in the classroom.

Questions around potential 'challenges' were:

- *What would be your nightmare scenario in using the robot? (S)*
- *Do you think that it is something where the novelty would wear off quickly? Why? (D)*
- *Let's pretend you've got a new job and your boss says to you 'Alright, here's a robot for your teaching', what would be the first things to go through your head? (S)*

These kinds of questions were asked to ascertain teachers' expectations and requirements around accepting an unfamiliar technology such as humanoid robot for use in their classroom, and to see whether they had previous negative experiences using new technology. Teachers were also asked to reflect on the novelty issue related to using this robot among primary-level students: how long students would engage with it, and what would happen if and when the novelty wore off.

It was expected that these three sets of interview questions would be used to classify high-level meta- themes. However the way the teachers interpreted the questions meant that the schema for meta-themes was revised and four different meta-themes were recognised based on the frequencies of teachers' most common responses to questions and the (sometimes unexpected) emphasis they gave to certain topics. The meta-themes were accordingly re-classified and are listed below with their associated subthemes. These are presented in detail in Section 5 and discussed further in Section 6.

1. Teachers' **pedagogical strategies**

The robot as a tool

Group or individual learning

Interactiveness: The robot as teacher assistant and

The robot as learner

Types of learners

2. Potential for student **engagement**

Attraction

Distraction

Novelty

Ownership

3. **Curriculum** factors

Curriculum fit Skills

4. Teachers' sense of **preparedness** to use the robot

Expertise Resources

Training

Technical support

Time allowed for preparation

The classification of themes and how the data was coded are also presented below in Figure 4.1 as a concept map (Kane & Trochim, 2009). A concept map is a graphical representation showing relationships among concepts. Concepts are shown as boxes or circles, and are connected to each other with arrows. The lines or arrows indicate relationships between boxes or/and circles. The thematic concept map shows the hierarchical structure of the coding tree.

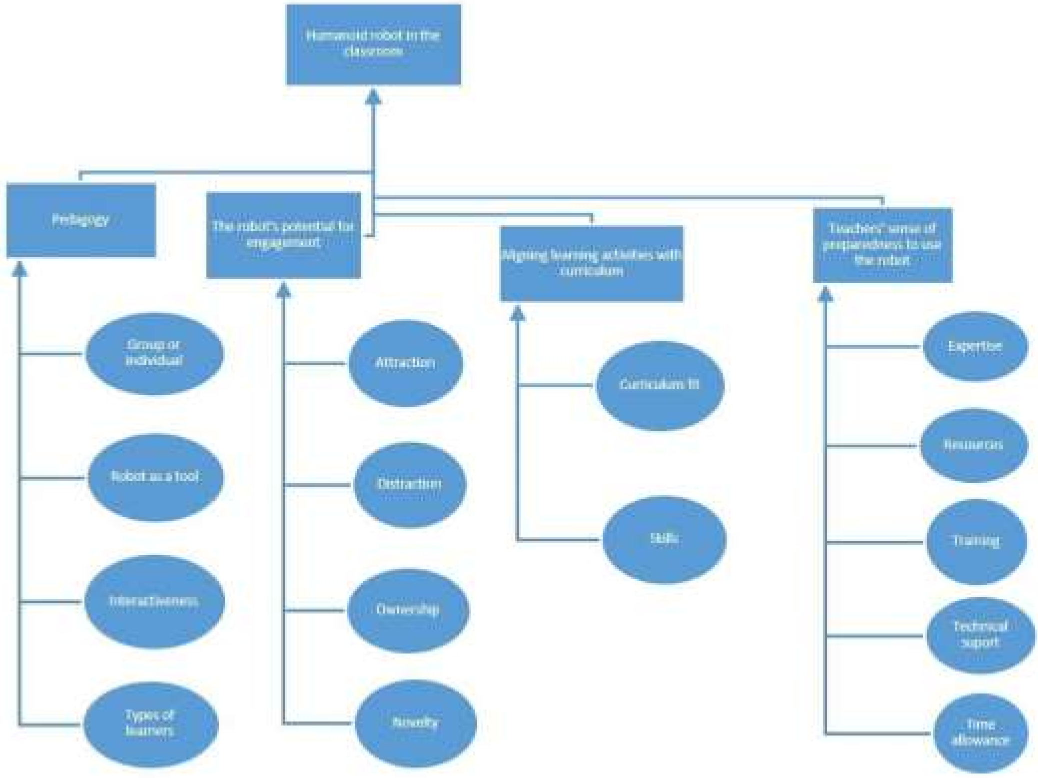


Figure 4.1: Thematic concept tree for the interview and open-ended written data

In this diagram, circles represent child nodes/sub-themes as delineated by NVivo, while the arrows indicate relationship between child nodes and parent nodes, which are shown as boxes.

Another graphical representation, called a tree map, shows the frequencies of teachers' responses for a specific topic (Figure 4.2). For this analysis, theme frequencies were generated only for themes that emerged in the teachers' responses. For example, teachers discussed and shared their ideas and thoughts about curriculum, which was (unexpectedly) the most frequent topic that teachers discussed during interviews. In this tree map, related sub-themes are shown in one box. For example, attraction, distraction, novelty and ownership are classified as sub-themes of 'Student engagement', and are accordingly placed in the one box.

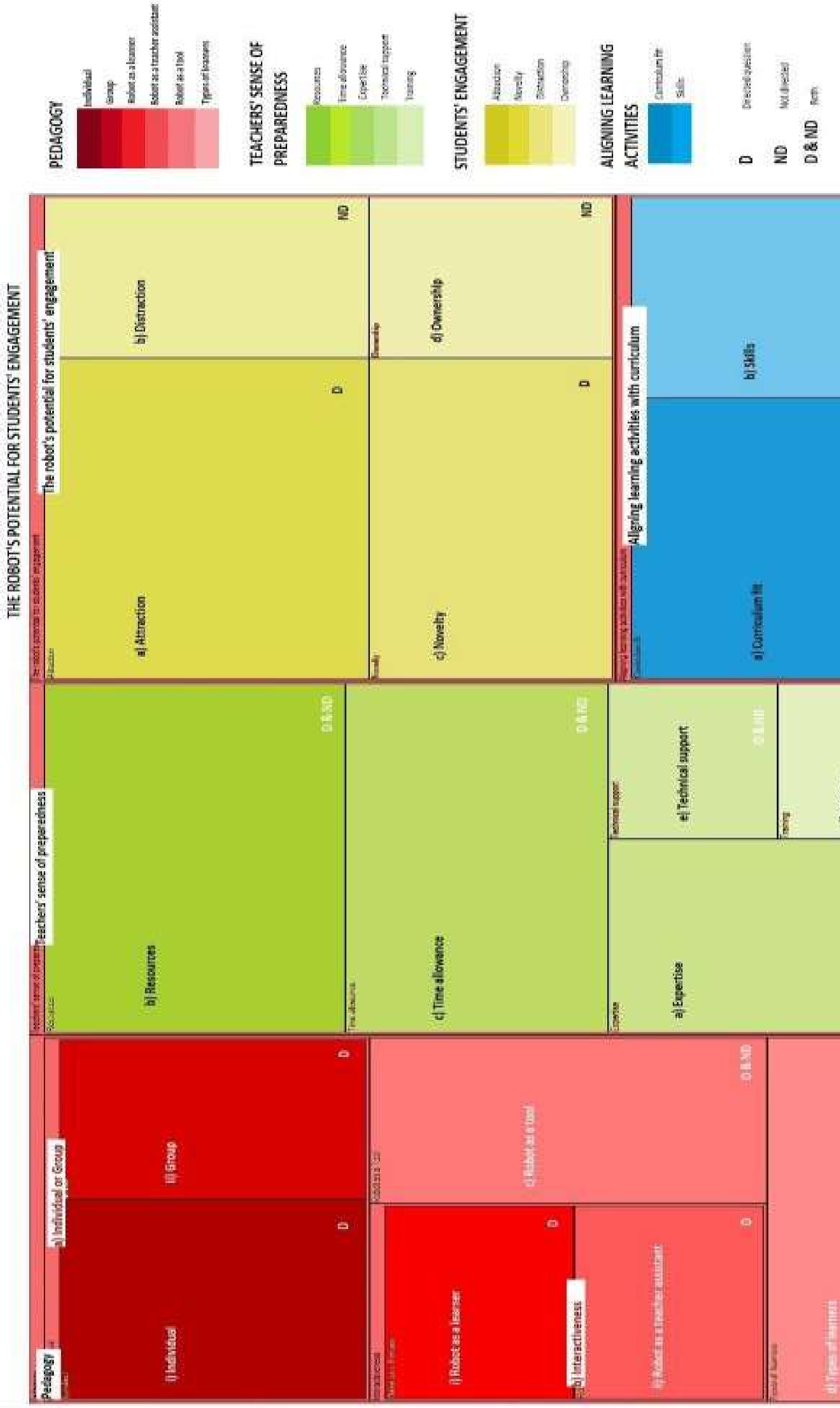


Figure 4.2: Frequencies of teachers' responses for interview questions, and coding in NVivo (See appendix 12 for each section separately: pedagogy, teachers' preparedness, students' engagement and curriculum alignment)

4.5.1 Meta-theme 1 - Pedagogy

Questions around potential 'use' sought to establish what types of teaching and learning would be supported by the teaching robot, and the teachers spoke about their pedagogical practice in response. As will be discussed below, all the question sets for the interviews had a pedagogical focus to some extent, but the 'use' questions in particular were designed to draw out, if possible, the teachers' own range of teaching methods, their views on the kinds of tasks or activities students could undertake with the robot and how these might play out in the classroom. The 'use' questions are listed below (with OE and D again referring to open-ended and directed questions):

- *How would you use the robot with students in the classroom? (OE)*
- *Would you use this technology as a group or individually? (D)*
- *Would you use it as a learner rather than as a teacher? (D)*
- *How could this robot fit into your classroom? What tasks could it do? (OE)*

The meta-theme 'pedagogy' was derived after reviewing teachers' responses to the above questions. These responses were then coded for frequency and emphasis into six sub-themes: the robot as a tool/device/machine, with groups, with individuals, the robot as a learner, the robot as a teacher's assistant, types of learners. Some of the responses fitted better with other meta-themes (especially those related to the last question around 'fit' and possible 'tasks'—see below). The interpretation underlying each of the 'pedagogy' sub-themes is described as follows.

Sub-theme P1 - the robot as a tool/device/machine

Even though this was not part of a directed question, all but one of the teachers spoke of the robot as a 'tool', 'device' or 'machine':

> *It becomes just another tool like the way a laptop or dictionary or IPad is used in the classroom. (John)*
>
> *The learning tasks are designed for collaboration and so the technology just acts as a personal tool to enable contribution. (John)*
>
> *Definitely, [it's] a teaching and learning tool. It's an exciting teaching tool… (Frank)*
>
> *In the future, you could possibly use it as a tool for rotations, having a table with a group of students and they might be working on special skills. (Frank)*
>
> *It's an engaging tool. (Jannie)*

You could use this as a shared device... (Steve)

... [students] imprint emotions on it that obviously don't exist because it's a machine. (Steve)

I like the idea they can program it to do certain things; they take the ICT aspect of a learning tool to a different level. (Tina)

Because this robot has humanoid features and the ability to interact socially with students, it was hoped that teachers would share their thoughts on its possible use in interactive activities in the classroom, and in some cases they did (see below). However, the teachers' (unsolicited) notions of the teaching robot as a 'tool', 'device' and 'machine' seem to ignore its humanoid qualities. In particular John's reference to the robot as 'just another tool' reflects this attitude. John's second statement above also accords with the common conceptualisation of teaching robots by teachers in other research as 'scripted, reactive machines' (Kennedy et al, 2016). In particular, the way John stressed the idea that "the learning tasks are designed for collaboration" and the robot "just … enable[s] contribution" strongly emphasised the pedagogic role of teachers and/or designers as paramount in the use of the robot for educational purposes. There is less overt critique reflected in Steve's and Jannie's reference to the robot as a 'tool', 'device' and 'machine', above, and Tina's comments about the robot "tak[ing] … a learning tool to a new level" can be interpreted in a more positive light.

Sarah's comments seem to reflect more of a sense of the robot as a 'humanoid' agent than do those of the other teachers, in that she did not use the term 'tool' and also she frequently referred to the robot as 'him' rather than 'it'. For example:

*... boys who are building Lego all the time, they will be more interested in **him** (Sarah)*

Sub-themes 2 and 3 - using the robot in groups or with individuals

The teachers were asked directly in a double-question whether they would consider using the robot to teach students in a group or whether they would choose to use it with individual students. The directness of this question made responses more frequent in the transcripts, boosting its level of prominence in the NVivo analysis. The purpose of the questions about group or individual work was to tease out each teacher's own preferred teaching methods when using educational technology in general and their thoughts on which teaching methods would work with the robot. The teachers could envisage using the robot either with small groups (rather than with a whole class), or among individuals.

Sub-theme P2 – use of the robot with groups

The teachers reacted positively to the idea of using of the robot in small groups. Typical comments advocating this teaching strategy were:

> *You could possibly use it as a tool for rotations having a table of a group of students and they might be working on a special skill. It could fit, in the sense of groups or group situations. (Frank)*

> *We had reading groups, where one teacher had three or four groups. One reading group could work with the robot. (Jannie)*

> *I think in a group—maybe programming to introduce certain things to the whole class. (Jannie)*

> *You could use it … in a small group, but it depends on the activity. Programming in late years in [primary] school would be a small group activity. (Steve)*

> *We have groups of kids working on literacy and maths, it could be with one of the groups helping them ... (Tina)*

The teachers' positive comments on using the robot for work in small groups accord with notions in the literature about constructionist approaches to learning being a natural fit with teaching strategies involving education technology (Packer & Goicoechea, 2000). Other research has shown that teachers tend to envisage the use of humanoid teaching robots in this way and, in particular, in terms of small groups rather than 'plenary' teaching (Flannery & Bers, 2015). However Tina also remarked in her interview:

> *I could see it being engaging for the students if the whole class was together and we did some sort of activity together as a class. (Tina)*

Sub-theme P3 – use of the robot with individuals

Teachers also envisaged using the robot with individual students, for example in one-to-one reading activities or helping students with 'special' learning needs. Typical examples were:

> *[Students could use this robot] individually. If you've got struggling students, really not getting into it, or maybe they missed lessons, then they can catch up with the robot—'Here is your activity and if you have any questions you can ask the robot'. (Frank)*

> *[I'd use it] individually, you know like reading one-to-one, working with the robot when I'm doing something [else]. (Jannie)*

Maybe [I'd use it] with some special students that have particular difficulties and need to do a more individualised program, for example maybe English as a second language. Or [if they were] in other kinds of difficulties, they could work one-to-one. For example next door they have one autistic student—they could get help individually. (Tina)

Sub-themes 4 and 5 - using the robot as a learner or as a teacher's assistant

The teachers were asked directly in a double-question whether they would consider using the robot as a learner or as a teacher's assistant. The directness of this question made responses more frequent in the transcripts, boosting its level of prominence in the NVivo analysis. The purpose of this question about group or individual work was to probe further as to whether the teachers would be open to novel approaches using unfamiliar technology. Because this robot has humanoid features, and in particular the ability to interact socially with students, it was hoped that teachers would share their thoughts on its possible use in interactive activities in the classroom.

Sub-theme P4 - the robot as a learner

The use of the robot as a 'learner' had been shown to the teachers just before the interview began in a video (see full description in Section 3, above). The video showed school children taking the role of teachers themselves, teaching the robot language skills in order to reinforce their own learning. Then, in their interview, individual teachers in this study were asked directly whether they would consider using the robot in this way.

In general the teachers were positive about the robot-as-a-learner strategy and indicated that they thought it could encourage students in their learning.

That will be really cool if kids are able to take their learning into their own hands and teach the robot to do [something]. I think they could … teach the robot how to spell or something...

They would know [then] that they can teach someone else too. (Jannie)

I was most impressed with that [in the video]. Because the child teaches the robot to hand- write letters well and recognise words, etcetera, that assists that child in hand-writing and learning words. (Steve)

Sarah had various ideas about using the robot in this way in her 'prep' class:

[The students] would be a big brother or sister to him and they would act responsibly trying to teach things that would help their [own] learning. (Sarah)

[A good] use for him in prep would be … as a learner when the children have the opportunity to teach him sounds like a particular letter in the alphabet, for example, 'this letter makes this sound'. For them it would be an opportunity to consolidate their learning and to consolidate their knowledge. (Sarah)

He could be a learner for this simple correspondence like connections or you know this number of dots you can use this new role matching the things like that. (Sarah)

Sub-theme P5 - the robot as a teaching assistant

The use of the robot as a teacher's assistant had also been shown in the video. The teachers spoke in positive terms about the potential for this strategy, especially in that it could allow them to distribute their own teaching time more efficiently:

If kids were doing an activity they could ask, rather than coming up to me saying ' I am unsure about this sentence' and [the robot] could answer them—maybe something like that

… for maths. (Frank)

If they worked in rotation and someone was at the front working on Mathletics, and … if it could be programmed to know certain things to explain to them—that would possibly be helpful. It could be a teacher's assistant. [If the students said] 'I do not understand why this is doing this', the robot could explain. (Frank)

It could be teaching kids in an interactive way. Those kids that are missing out …, they could come back and catch up. In this sense the robot could work well. (Frank)

The best use for [this robot] in prep, would be [as] a teacher. (Sarah)

They've almost got two teachers at a time; it's another level of expertise. If they are unsure and I am busy with a group, they can actually get in to a concept, okay its works and I am gonna use it in my follow up questions. So I think there's lot to be gained from it. (Frank)

[I would use it] more as a teacher's assistant. I would program it to give instructions, and [it] would go with a group and the kids would listen to the specific

instructions. It could repeat the instructions if [the students] couldn't understand. That would be good rather than me explaining again and again, getting interrupted with the group I have on the floor ... So that would allow me to focus more on my group … and not [be] interrupted. (Tina)

Constructivist approaches featured in teachers' responses to the question about 'the-robot-as- learner'. In general, the teachers' feedback was that the robot could be a learner and the children could act as an active user teaching the robot, the rationale being that sometimes children learn the content in greater depth as preparation for teaching someone else. Other studies have shown that educational service robots can take various roles as co-learner, peer or companion and engage in active spontaneous participation (Okita, Ng-Thow-Hing, & Sarvadevabhatla, 2009) and that children can learn along the way as they teach the robot (Mubin et al., 2012).

In general, research about children in groups having robots as teaching assistants has been positive (Okita, Ng-Thow-Hing, & Sarvadevabhatla, 2009). The interviewed teachers had various ideas about whether they would use the robot as a teacher assistant or a learner or in both roles in their classroom practice. As Frank noted, the role the robot could play would probably depend on the students' learning tasks. In this sense the interviewed teachers touched on similar ideas to those described by Mubin et al. (2012) who found in another study that the choice of the robot's role could depend on the content, the instructor, the type of student and the learning task.

Sub-theme P6 – use of the robot with different types of learners

The teachers were specifically asked: *Do you think the robot would work better for some students than others? Why?* The purpose of this question was to probe for teachers' ideas about the flexibility of the teaching robot. The directness of this question made responses more frequent in the transcripts, boosting its level of prominence in the NVivo analysis. Responses include:

It could cover everybody… (John)

For a verbal learner, listening well would benefit [the student]; for a visual learner we'd need it to draw something. (Frank)

I think [it would work better for] students who need the next step, or a little bit more challenge … who maybe need inspiration or something else to develop their learning. (Jannie)

I think it would work with kids who require individual attention consistently for learning. (Steve)

… every student learns differently and even iPads work better for some students than others. Demonstrating ideas by drawing works better for some than others. Every student learns differently. (Sarah)

I would assume students who are more into technology and science and robotics [would benefit more]. Boys who are building Lego all the time will be more interested in him than some of my shy girls who … don't take risks. (Sarah)

Maybe some special students who have particular difficulties and need to do a more individualised program [would benefit more], for example maybe [students in] English is a second language [programs], or with other kinds of difficulties … Or maybe weak students. (Tina)

… different students learn differently ... For learning fractions, some kids learn visually [but] some like to manipulate magnetic fraction pieces—they learn better from holding things in their hands. (Tina)

Most of the interviewed teachers thought that this robot could work for both stronger and weaker students but they emphasised using the technology in the right context with the right pedagogy.

Frank also discussed the need teachers have to deliver content in various ways:

Sometimes you can teach something one way, but there are three or four different ways [to deliver it]. If you had a robot, you could try all the different ways—'Okay, this is one way, have a go. Here's different way, now have a go and here's the third way. Now you can work out which one is best for you'. (Frank)

4.5.2 Meta-theme 2 - The robot's potential for engagement

The original set of questions around potential 'benefit' is listed below, where S, D and OE stand for 'scenario', 'directed' and 'open-ended' questions:

- *What would your dream scenario be for using the robot?(S)*
- *Do you think the robot would engage students? Why?(D)*
- *What contributions do you think the robot could make to your classroom?(OE)*
- *What skills do you think a student could gain from using a teaching robot? (OE)*

- *Do you think the robot would work better for some students than others? Why? (OE)*

Questions about potential 'benefits' offered by the robot were originally designed to invite the teachers to reflect on how their students' learning might improve when using it. However, because the teachers were asked specifically whether they thought the robot would 'engage' students, the directness of this question made responses around 'engagement' very frequent in the transcripts, giving it a high level of prominence in the NVivo analysis. As well, four out of six teachers envisaged 'dream scenarios' of 'engaged students' (this was before 'engagement' was mentioned in the directed question) (see below). Although there is an argument for coding responses to such questions under the 'pedagogy' meta-theme (see Discussion, Section 6), both the volume of response around 'engagement' and the unexpectedly different and more complex aspects of 'the capacity to engage' that emerged in the analysis (and their relationship with debates in the literature (Bunz, 2016), meant that it was decided that 'engagement' merited a separate category.

In addition, since questions about 'contribution' and 'skills' elicited a great many responses mentioning 'curriculum', even though this topic was not mentioned in any of the interview questions, it was also decided that 'curriculum alignment' also merited a separate meta-theme (see below , Meta-theme 3). Once again, there is also a relationship between curriculum and pedagogy, which will be discussed in Section 6.

Originally a separate meta-theme associated with 'challenges' had been envisaged, based on the following questions:

- *What would be your nightmare scenario in using the robot? (S)*
- *Do you think that it is something where the novelty would wear off quickly? Why? (D)*
- *Let's pretend you've got a new job and your boss says to you 'Alright, here's a robot for your teaching', what would be the first things to go through your head? (S)*

However, with hindsight the directed question from the 'challenges' set '*Do you think that it is something where the novelty would wear off quickly?'* seemed to relate strongly to 'engagement', or at least, that was how it was interpreted by the teachers, and so the sub-thematic structure described below reflects this interpretation instead.

As well, the first 'challenges' question invited teachers to imagine a 'nightmare scenario' arising from their use of the robot for education purposes. As five out of six teachers' 'nightmares' involved poor levels of engagement on the part of the students (see below), this gave extra support for the notion of 'engagement' as a powerful and distinct meta-theme.

Responses to the final 'challenges' scenario-based question ('*Let's pretend you've got a new job*…') are described below in Meta-theme 4 - 'teachers' sense of preparedness'.

The meta-theme 'engagement' was classified into four sub-themes: 'attraction', 'distraction', 'novelty' and 'ownership' based on frequency of response.

Sub-theme E1- attraction

All of the teachers thought the humanoid robot had the potential to engage students in the sense that they would find the robot appealing and fun. Most of the teachers commented that children like technology, they are very comfortable with it and they are able to use different types of technologies.

> *Yes, I have seen [this robot] here, in the school. The girls had [fun with it]. I think most new technology that's robotic has a sense of fun. (Steve)*

> *[Children] like technology, they like digital white boards, even TV screens, they're just engaged and they love it. (Jannie)*

> *Yes, definitely [the robot would engage children]. [Children] love technology. (Frank)*

> *Really probably what would be so good is how it would engage the children, particularly those troublesome boys you get in every class who are quite unenthusiastic and disengaged. I think they would be really keen … to learn from something like that. (Sarah)*

Some observed that children would be engaged with the humanoid robot because it is or looks "different" or "cool" or has a "humanlike" appearance.

> *If they get to choose out of me explaining to them on the board or a YouTube video, they'll choose the YouTube video because it's different to the norm. The kids will keep their eyes on [the robot] … [they'll] be wondering what it will say next. (Frank)*

> *Why does technology engage kids? Following robots is a little bit cooler than following a teacher, something like that. (Jannie)*

> *Definitely, [children would be engaged with this robot]. I think mainly because he is so humanlike and so huge—particularly the children that I teach, around 5 years old. (Sarah)*

The teachers also made connections between the robot's capacity for flexibility and interaction and its ability to engage. They noted that this would allow students to learn in different ways.

> *[Children] engage with technology. Having a robot, that's another way to involve or engage them. Being able to program it, give it gestures, make it recognise things—that's a point of view they would engage with. But even more they have control to make it do certain things; they can run a program to do this and that, it would definitely engage [them]. (John)*

> *It engages students. It provides for differences in learning styles. It can be interactive. It can be colourful and interesting. It can present information but in a different way. It can provide drill and practise for students. (Tina)*

However John, whose profile showed him to be the most well prepared to use technology among the six teachers, expressed concern about potentially negative aspects of the robot's attractiveness:

> *The nightmare scenario is shallow learning, for me in my role as a teacher and also as a director of ICT. With technology in classrooms, it's got to take learning technology from here to here and if you are just shining and flashing then you need added depth in learning.* (John)

Sub-theme E2 – distraction

John's vision of potential 'shallow learning' in the face of 'shining and flashing' education technologies also relates to issues around the potential of the robot to distract students from learning. In addition to John's abovementioned concern, the other five teachers' gave 'nightmare' scenarios involving poor levels of engagement on the part of the students. The teachers were not directly asked any questions about the robot's capacity to 'distract' students from their learning, so the extent of this response in relation to the 'nightmare scenario' question was unexpected.

> *I think kids mucking around with it, not taking it seriously. They are ignoring their learning, just starting to play with it and saying silly things, getting it to do silly things. (Frank)*

> *Kids would be getting silly, mucking around, too much excited by the robot. (Jannie)*

> *It would be a distraction when I could teach a simple lesson the 'old-school' way to achieve the same objective where that's all it may take. If it's distracting the*

children from the real objective then it's going to take a lot longer for them to just reach more than you could have taught them in the first place. (Sarah)

I am a bit worried there would be other groups doing something different, and they could be distracted by the robot. (Tina)

Too many kids getting distracted (not concentrating) too often if it was permanently in classroom. We would [need to] rotate it to different classes--how that would work, I don't know. Weaker students would be distracted by its fun aspects, because it does look very cute. (Tina)

Sub-theme E3 - novelty

The teachers were asked about 'novelty' issues with the robot. This question was asked to ascertain their ideas about how long students would be engaged with the robot and what issues need to be considered to maintain their interest over time. Most of the teachers referred to 'scaffolding' pedagogies in relation to this question, noting that if students could use the robot to undertake a wide variety of tasks and if the tasks continued to be achievable, then the students' interest could be maintained.

I think with this generation of kids whether novelty would wear off is with complexity. If they got it and they can only do say task 'A' and then there is no success and it is really hard to do the things, it would not be successful. It might be a little challenging but reachable and it allow them [kids] challenging to success. (John)

Some probably [would lose interest over time], but most no. If you use it for a variety of things in an interactive way, [the novelty] might not wear off. (Frank)

With younger kids perhaps I would think the novelty would wear off. (Jannie)

If it has only limited range of behaviours children eventually would become bored, just like [with] a toy. (Steve)

He would need to continue to be accomplishing more and more for the children to continue to stay more engaged. Like an iPad has updates where you could do anything and you can get more functionality on it, just the same as computers he would always need to do some impressive levels. As soon as people do what they *can do, they gonna say okay, it's awesome, eventually they are getting tired unless he gets better too. Novelty would wear off if he remains the same. (Sarah)*

If it is once or twice in a week, the novelty factor will remain in a very long time. Kids will be happy that robots are here now in classroom. (Tina)

Sub-theme E4 – ownership

Even though there was no direct questions regarding this sub-theme, teachers' comments showed that they value aspects of the interaction design that mean students could 'take ownership' of their learning. Examples are:

Students could be creating on their own instead of being led by something I want to do. Kids should be able to take ownership and to take action. (John)

That will be really cool if kids are able to take their learning in their own hands and teach the robot. That would consolidate what they understand or they learnt from their teaching. (Jannie)

The teachers' comments on how students could take 'ownership' of their work also demonstrates their support for constructivist learning approaches as offering the best way of using this robot. This theme is widespread in the literature, and a range of studies emphasise hands-on and creative aspects of learning with robots, along with the capacity of robots to engage children in learning through problem solving (Kabatova & Pekarova 2010, Yousuf 2008).

4.5.3 Meta-theme 3 - Aligning learning activities with curriculum

Aside from the 'engagement' and 'learner type' questions described above that have been subsumed into Meta-theme 2, the following questions remained around the notion of potential 'benefit':

- *How could the robot fit in to your classroom? What tasks could it do?(OE)*
- *What contributions do you think the robot could make to your classroom?(OE)*
- *What skills do you think a student could gain from using a teaching robot? (OE)*

As noted above, these questions had been designed with the assumption that 'dream scenario', 'fit', 'tasks', 'contribution' and 'skills gained' would be interpreted by teachers as a reflection on how the robot would be used or how students might benefit from the robot in terms of their learning.

However instead teachers often interpreted them in terms of whether activities using the robot could be integrated with designated 'curriculum'.

According to the Australian Curriculum Assessment and Reporting Authority (ACARA, 2012, p.9), "The national curriculum will detail what teachers are expected to teach and students are expected to learn for each year of schooling. The curriculum will describe the knowledge, understandings, skills and dispositions that students will be expected to develop, in sequence, for each learning area across the years of schooling".

Although the term 'curriculum' was not used in any of the questionnaire or interview questions, this was the largest emergent theme in the study. Possible reasons for this are discussed in Section 6.

Teachers had been shown a video at the beginning of interviews, as described in Section 4, depicting various classroom settings. It could be that the teachers were influenced to think about curriculum activities when they asked to watch the video, which showed teachers using the robot in the classroom in a range of content areas.

Sub-theme C1 - curriculum fit

The teachers noted this robot could be useful for language learning: reading sentences, breaking up words, recognising words, spelling, word sounds, structuring words and handwriting.

Typical responses were:

> *We've got kids who have English as a second language--it might be able to translate words for them. (John)*
>
> *Specific tasks could be using visual recognition of words ... the robot saying to the child what is this word and then the child reading the word back and the robot responding ... That sort of back and forth for word recognition. Also programming it to break up words into syllables then you could teach reading as well. That would be very useful and then also actually handwriting, tracing letters--actually physically tracing the robot's [handwriting] … I was most impressed with that [in the video]… That would be the application I would use it for in the school environment. (Steve)*
>
> *The big thing we focus on is social skills and obviously being able to read simple sentence. So letters... letter sounds, having some reading skill strategies. And numbers too, up to 20. (Sarah)*

I am not sure what it is capable of but a big focus in Prep is oral language skill and giving and following instructions ... approaching people in the right way like excuse me, thank you. So oral language, speaking and listening ... (Sarah)

It could work for maths or literacy, maybe spelling, testing kids' spelling. (Tina)

The teachers also mentioned science, technology, engineering and mathematics (STEM) aspects of the curriculum. They frequently referred to programming and described how the robot could be useful for learning programming, if used with a suitable age group.

It obviously crosses curriculum, it could work in science, maths ... I would really love to see ... students being able to program it to assist... (John)

Teaching kids how the technology works. Simple programming on how the actual robot works. Kids are interested this sort of stuff... Lots of kids will be interested in how it knows how to say words, how it moves back and forth. A mini project on how the robot works. (Frank)

If I had the chance, I would run a programming session how to make a computer game, I think kids will be interested. (Frank)

If you teach kids how a robot works, how programming works, how a computer works ... it's another level of expertise that they are unsure of. (Frank)

...maybe [I'd use it for] programming, to introduce certain things to the whole class ...the older kids would definitely love that. (Jannie)

If I was a teacher of grade 5, then teaching kids to program--that would be awesome. Most 12 or13 years old kids are really keen to learn programming and there will be more opportunities for it as time goes on and technology becomes more part of our world.

Programming is quite mathematical thinking ... (Sarah)

Programming skills for the kids year 7 to year 9. Having a robot in their environment and thinking what tasks could it do. (Steve)

Well in my area, teaching and software development, I don't really see any immediate application ... other than having my students actually program it by themselves. (Steve)

As a technology project I am not sure he could fit into my year level ... but he definitely he could fit into an older year level as a technology project. (Sarah)

The teachers were interested to discuss which curriculum activities could fit with the robot. They mentioned various examples that could fit, including language learning, programming, literacy and numeracy, positional language, writing assistance, and technology projects.

Sub-theme C2 - skills

The question directed to the teachers about 'skills' inculcated by learning activities using the robot also unexpectedly elicited responses related to curriculum. Here the teachers were asked:

- *What skills do you think a student could gain from using a humanoid teaching robot?*

The teachers discussed various ideas about what skills students could gain using this humanoid robot. Typical responses were:

Computational thinking, sequential, collaborative and design thinking, robotics, programming, creativity, writing, maths, science—I would struggle to not find any benefit to a classroom. (John)

I would assume computing skills, learning directions (left right up down forth back), location aspects of maths… I think it would foster creativity… (Tina)

Spelling and math skills if I set up particular tasks in a group. (Tina)

I think it could be really nice to teach him appropriate social skills and then he can model them to watch, he could explain what he did that's wrong and what you should have done is this. We focus a lot on values and respect and those concepts. It would really be fun to see him demonstrate the right way or wrong way to do things and the children could explain why. (Sarah)

In sum, the teachers' thoughts related to the curriculum (both in terms of 'fit' and 'skills') conform to the following areas:

Literacy:

- *The robot could read a book with a group of children (3/4 children), and ask questions to students. (Jannie)*
- *Children who have difficulty with hand writing, they would use the application for learning handwriting with the robot. (Steve)*
- *Children could learn grammar and punctuation that sort of thing ... (Frank)*
- *Children could learn spelling and tense ... (Tina)*

Numeracy:

- *The robot could explain or help children with 'Mathletics' ... (Frank)*
- *The robot could ... teach them counting, addition, subtraction and division, picking up blocks for physical demonstrating. (Steve)*
- *The robot could teach children about location aspects of maths. (Jannie)*

Positional language/ learning directions/social skills:

- *… learning directions... (Jannie)*
- *... appropriate social skills... (Sarah)*

John, Steve, Sarah and Tina noted the robot would be useful to stimulate learning of language skills; they thought it could help students with spelling, pronunciation, reading and writing. Most of the teachers also gave feedback on how children could use this robot to learn programming, which age group would be suitable, whether it could be a group or individual activity, and what benefits children could gain using the robot to learn programming.

4.5.4 Meta-theme 4 - Teachers' sense of preparedness

This meta-theme arose from the original question set about 'challenges', designed to gauge teachers' expectations and requirements to accept an unfamiliar technology, such as a humanoid robot, for use in their classroom, based on their previous experiences of using new technology.

- *What would be your nightmare scenario be in using the robot?(S)*
- *Let's pretend you got a new job and your boss said to you 'Alright, here's a robot*

for your teaching', what would be the first things to go through your head? (S)

This theme also drew on the following open questions in the questionnaire:

- *What are the available technologies at your school to use in the classroom? (OE)*
- *If you do use technology in the classroom can you describe some examples including the subject, the technology, how the technology is used, how successful is the use of the technology compared to traditional teaching methods. (OE)*

Most teachers wrote lengthy replies to these two questions and the resulting text was analysed together with the interview transcripts. This provided a rich and detailed view of the teachers'

'preparedness' to use a teaching robot. The sub-themes that emerged from the analysis of this data were: 'expertise', 'resources', 'training', 'technical support' and 'time allowed for preparation'.

Sub-theme T1 - expertise

The teachers gave examples of their expertise in using different educational technologies in the classroom for teaching various subjects.

> *I use technology in all subjects. In Literacy I use the iPad to plan, research and create writing, document the writing process and to provide instant feedback. In Maths I use the iPad to visually document student working out and to extend or remediate. I use the iPad and the Apple TV in the classroom to create a presentation space and to brainstorm collaboratively. I use an iMac to allow students to publish their work to a global audience. We use Makey Makey's to allow students to invent and problem solve. We use programming applications like Hopscotch and Tynker to develop computational thinking and to enable students to understand the inner workings of machines, robots and computer applications. (John)*

> *As a teacher, I am always encouraging students to explore using ICT to help them learn further… I often use my large flat screen TV which is connected to the internet to engage students and also show examples. YouTube and certain websites are great for showing a different way from what I may have personally taught the students. I find this successful as children really enjoy moving pictures and colours and the fact that you can always get different methods for teaching skills from the internet. We also use iPads for research and last term we used*

them to create TV advertisements. The students use iMovie and loved using the technology… (Frank)

We use iPads for videoing role plays where the children practise their social and oral language skills. We also use iPads to take photos to demonstrate our learning in maths- i.e students may complete a hands-on task like making a pattern and then photograph their work to show the class at the end of the lesson. We took photos outside of the children demonstrating positional and directional language concepts in the playground. We use Smartboard software to model concepts like ten frames and addition/subtraction software. We use interactive websites on the Smartboard. We record our voices on the iPads to explain our writing/drawing when the teacher is working with a small teaching group and cannot scribe work. We use story-telling apps to create narratives and develop our concepts about print. (Sarah)

The Mathletics program is used often, individually, at individual students' level - excellent to support our maths topics in a different and more fun way. We use iPads to record things, to make short videos to support topics we're working on… I have used interactive whiteboards in the past … I also use Youtube clips, often to engage and entertain the students. We use the Internet mainly for research purposes. (Tina)

Steve and Jannie did not respond to this open question in the Questionnaire (Q.12). However, they did answer other questions from which it is possible to extrapolate some features of their expertise. Jannie noted that she was enthusiastic about and interested in using technology in the classroom, and she was experienced in using computers, iPads and interactive whiteboards in her classroom. Steve is a technology leader in his school, and is experienced in software development

Sub-theme T2 - resources

The teachers' responded at length about 'resources' available to them, partly in relation to Question 12 in the questionnaire: *What are the available technologies to use in the classroom?*, but also throughout the interviews. They described the technologies they use, how they use them in the classroom and how children have benefited from them. They expressed some concerns about the robot as a somewhat expensive 'resource' and wanted to know more about its 'limitations'. Typical examples were:

One, [the robot] is probably expensive, and other points are working position and battery life. [The robot] has to work and be reliable. (John)

… Knowing its limitations will be the best thing. Budget is a school council decision. If ICT decide to buy a new tool, they work out what will be best to use, where we can use it and for which level. (Frank)

… what are its limitations? (Tina)

The teachers also shared their stories of access to new technology tools in the classrooms. Most of them seem to feel their schools need more ICT equipment in their classrooms. Typical comments about lack of resources were:

In an ideal world I would have one-to-one computers or iPads as students could then access them when needed and not have to wait ... I would have certain programs or apps which I could use to communicate to students ... which would keep the classroom more paper free. (Frank)

Throughout year levels computers are used daily and iPads are available, albeit there aren't as many to use. As a teacher, I am always encouraging students to explore using ICT to help them learn further. (Frank)

Students used a one on one iPad program in Grades 5 and 6, and a class set of iPad minis were shared amongst the year levels. Apple TVs and interactive whiteboards were in use in the classroom daily. (Jannie)

We use iPads with a partner because we do not have enough devices for each child. (Sarah) [There are] problems with the number of available computers ... (Tina)

Sub-theme T3 - training

The teachers also provided suggestions on what training they would require for the use of any new technology. Most of them noted their expectation of receiving training before using a new technology.

[I would want to know] when is my professional development, what budget have I got, what time allowance have I got, what do you want me to achieve with [the technology], what objectives have you got? (Sarah)

We used Apple Macs this year (we had IBM machines in previous years). We haven't received training and we can't print from them and there have been an inordinate amount of technical difficulties, no or intermittent WiFi connection - the students and

I are fumbling along and trying to do the best that we can. No professional development has been provided...This is very frustrating! (Tina)

I am happy with brand new things, open to change, open to progress but I would like to get appropriate training ... Having brand new things without training, it is very frustrating. (Tina)

Sub-theme T4 - technical support

In the interviews, the teachers emphasised the importance of technical support:

Setting up the class and the robot does not work--basically [that] is what every teacher's nightmare scenario would be. You planned to use the technology ... and then it doesn't work. Then you have to think quickly--what I am going to do instead? ... The learning itself would be critically linked to the use of technology, so then you may have to modify the way you do the instruction to get the learning across. (Steve)

We have a techie to help with problems but he is only here for 2 days a week. We probably need, as a whole school, about twice that allocation of time. It would be nice to have an expert to assist in incorporating technology into the classroom. (Tina)

Sub-theme T5 - time allowed for preparation

The teachers said they would need to receive time to learn about any unfamiliar technology before using it in the classroom. They would like to be a learner first, playing with the robot themselves and/or observing those who are able to use it.

[I would like to be] learning by myself, just figuring out how it works, what it could do, what projects we could do [with it]? (John)

Occasionally I'm not very familiar with a program, but I normally make sure I've had a play around with it before I introduce it ... How can I use it in my classroom? I take it home or play with it after school, [find out] as much as I can know about it by trial and error, its limitations, which curriculum it could fit ... (Frank)

I suppose the nightmare scenario would be you put in huge time and effort into making something like a robot fit into your classroom and you don't achieve what you want. (Sarah)

When we got iPads, I took one home during Christmas to know more about it... Before going to use it in a classroom successfully, you need to understand it back to front. I would like to know [the robot] first. (Sarah)

I would like to be a learner first, to know everything that it could do, how someone else could use it. (Jannie)

I'd take it home, and ... let my sons play with it. I think they are the target audience. (Steve)

Now that the program is set ready to use in classroom, now all that has happened, how can we better use [technology] and make better use of our time? Not losing so much time in trying to sort out constant problems ... We also need time to play with new technology, but we don't usually receive this ... [I would like] time to be trained adequately, with follow-up support, if needed ... and time allowance. (Tina)

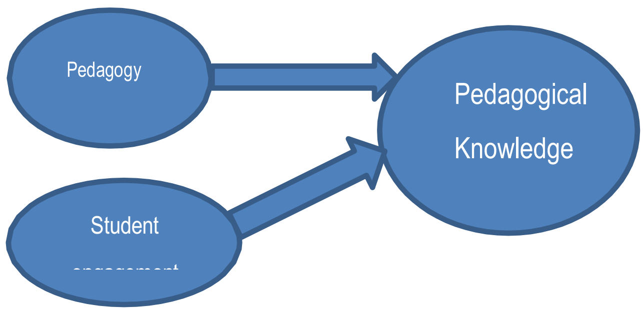
Various studies have shown that teachers' training and the benefits of using technology are closely related (Clements and Sarama 2003, Magyar et al. 2014). According to Magyar et al. (2014), the aim of professional development activities should be to help teachers improve their technological skills and their teaching competencies concurrently. It seems that both developmentally appropriate technology and well-trained teachers in preschool programs are needed; otherwise interventions may be detrimental. However, more research is needed to determine whether this is the case and to find the right balance.

Most of the teachers noted their expectation of receiving both training and time for preparation before using any new technology. They were concerned about technical difficulties and about lack of adequate support. Some recounted earlier stories of frustration at not receiving training before using new technology or not receiving enough technical support while using it in the classroom, especially when the technology malfunctioned.

4.6 Discussion

The themes derived from the teachers' input can be categorised and explored in terms of the TPACK framework described in Chapter 2. As discussed, TPACK provides a means of 'unpacking' the kinds of knowledge teachers bring to the technology implementation design process and checking that the design draws more extensively on relevant knowledge about technology-enhanced learning. The spread of responses described above shows that this study was able to do this in the context of a localised setting. The narrowly scoped, strongly contextualised aspects of this study exemplify the kinds of DBR methods presented in Chapter 3. As noted there, DBR methodology constrains the ability of a study to make generalisable claims on a number of fronts, and this includes providing empirical support for TPACK as a theoretical framework. However DBR is able to model “factors which make that intervention successful in a given setting” in ways that mean it can be used and adapted by others (Flannery & Beers, 2015, p. 200). It is therefore expected that elements of this study will suggest ways of improving the educational technology implementation design process (see Chapter 7).

Connections between the themes explored in Study 1 and the TPACK framework are demonstrated below. The following three subsections show how the meta-themes emerging from this study are each related to the three main elements of TPACK: pedagogical knowledge (PK), content knowledge (CK) and technological knowledge (TK).



Figurer 4.3 (a) Meta-themes 1 and 2 correspond to PK

4.6.1 Pedagogy and student engagement as pedagogical knowledge

Pedagogical knowledge (PK) is knowledge of teaching and learning, including teaching methods, lesson planning, classroom management, learning theories and how all these relate to learning outcomes (Chai, Koh & Tsai, 2013; Schmidt et al., 2009, p. 127). In this study, teachers shared their pedagogical knowledge in extrapolating from their own experience and reflecting on how the robot could be used.

In general, the teachers indicated that the robot could be used for the kinds of flexible, learner-centred activities that are already a part of their classroom practice. This was shown by their ideas about the use of the robot in small groups and with individual students, their positive attitude to the ‘robot-as-a-learner’ strategy and their ideas about flexible delivery of content for different types of learners.

As already noted, the use of robots in education shows connections to constructivist learning theory and hands-on approaches that can increase the motivation of students

(Kabatova & Pekarova 2010; Piaget, 1983). It has been shown that by exploring and using robots in a primary school program, students can develop a range of important skills (Wei et al., 2011). Teachers can use robots for multiple purposes, especially if they are easily customisable (Magyar et al. 2014; Flannery & Bers, 2015). The teachers in this study clearly thought of the robot as a potentially engaging tool, machine or device that could be adapted for various educational purposes, even if they were not always certain as to the associated learning outcomes. Similar results from other studies have shown that teachers generally accept humanoid educational service robots as 'interactive teaching tools' (Reich-Stieber & Eyssel, 2016). However the teachers in this study also recognised that using the robot in flexible ways mean having to program it for that purpose.

The interview teachers also mentioned that they would be open to accepting unfamiliar technology, but they were concerned about their preparedness for it. As noted in Chapter 2, studies in Europe and Asia have shown that in primary school education teachers demonstrate more 'cautious' attitudes towards humanoid educational service robots than in secondary level schooling (Kennedy et.al, 2016). Other research has suggested that there are barriers to the adoption and use of robot technology by teachers, and that although teachers are generally positive, there are concerns over 'fairness to access, the robustness of the technology, and potential disruption to classrooms' (Kennedy, et al., 2016).

Engagement was an important topic to the teachers, in positive and negative senses, and in ways that relate to the abovementioned concerns in the literature about 'disruption in classrooms' (Kennedy, et al., 2016). Issues around student engagement with technology-based learning activities have been extensively explored in the literature (Christenson, Reschly, & Wylie, 2012). The robot's capacity to engage primary-level students was generally indicated to be a plus by the interviewed teachers. However the possibility that this feature might distract children from their learning was also expressed frequently. Other studies have also recorded this opinion in relation to students' engagement while learning from humanoid robots (Clements & Sarama, 2002; Magyar et al. 2014; Serholt & Barendregt, 2014). Concern about 'shallow learning' was also captured by the pedagogy theme in the current study - this will be investigated further in Chapter 6.

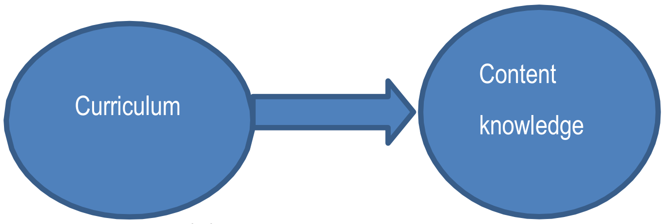


Figure 4.3 (b) Meta-theme 3 corresponds to CK

4.6.2 Curriculum as content knowledge

Within the TPACK theoretical framework, content represents the subject matter that teachers must know about and draw on in their classroom practice, including information, skills and the ways this knowledge is different for various content areas (Chai, Koh & Tsai, 2013; Schmidt et al., 2009). Knowledge of content also guides expectation of outcomes. The Australian Curriculum, Assessment and Reporting Authority note that students need to "develop knowledge, understanding and skills in the discriminating, ethical, innovative, creative and enterprising use of a range of technologies" (ACARA, 2012, p.3). Clearly it was very important to the teachers interviewed in this study that activities designed with the use of the robot in mind fit with designated curriculum, and, as noted above, this proved to be an unexpectedly large theme in this project. The teachers' suggestions related to learning activities in the following content areas: literacy, numeracy, physical activities, positional language, learning directions, and social skills. They placed particular emphasis on its possible use for learning language skills and programming.

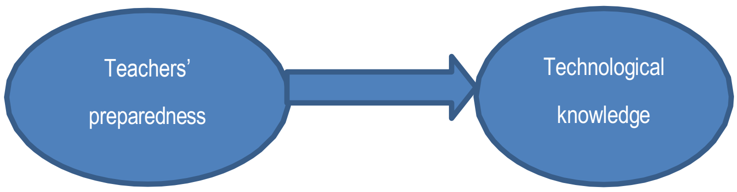


Figure 4.3 (c) Meta-theme 3 corresponds to TK

4.6.3 Teacher preparedness as technology knowledge

Technology Knowledge (TK) refers to the knowledge of using various technologies including software and hardware and ranges from low tech knowledge to advanced digital technologies (Mishra & Koehler, 2008). In terms of preparedness of teachers, the study confirms earlier findings about the importance of training and technical support (Mishra & Koehler, 2008). The teachers interviewed in this study were clearly experienced in using education technology and interested in the robot. However they had a number of concerns about their preparedness to use it and the robot's limitations. They gave an account of their 'expertise' in using educational technology tools and they discussed the importance of effective training, technical support and time allowed for preparation before introducing this robot into the classroom. In another study, Schmidt et al. (2009) note that 'using TPACK as a framework for measuring teaching knowledge could potentially have an impact on the type of training and professional development experiences that are designed for teachers' (p. 125). At this stage it is unclear how much training support and time for preparation these primary school teachers would need to successfully use this humanoid robot in their classrooms. Other studies have also emphasised the importance of professional development and training, and showed how this can affect teachers' TPACK (Koehler & Mishra, 2005; Mishra & Koehler, 2006; Schmidt et al., 2009). And finally, the TPACK framework offers the potential for follow-up evaluation when the implementation design reaches the stage of classroom testing (Koh, Chai, & Tsai, 2014).

4.7 Summary and conclusion

Implementation design needs to take into account the complexity of classroom settings and the fact that teaching is a multi-faceted activity (Fenstermacher, 1994; Mishra & Koehler, 2006). In this study, the input from the participating teachers helped to factor some of this complexity into the design process. This study found that the teachers involved could envisage a range of feasible ways to incorporate the humanoid robot into their teaching practice in order to enhance their students' learning.

Key PK-related design requirements for the next phase of the design process were:

- The humanoid robot should be able to be programmed to provide a flexible learning environment for different kinds of learning activities and different kinds of students.
- The robot should be able to provide strong support for student-centred learning.
- The robot's interactive capability should be utilised in any learning activities.
- The robot should be engaging and fun to use.

Key CK-related design requirements for the next phase of the design process were:

- Learning activities should be aligned with relevant curriculum
- The robot could fit with language and literacy or programming areas of curriculum.

Key TK-related design requirements for the next phase of the design process were:

- Teachers would require training and time allowed for personal learning and preparation before using this robot in their classroom practice
- Teachers may need programming expertise to enable flexible/interactive use of the robot in the classroom.
- The robot would need to be robust, not prone to malfunction, and able to be used with limited access to technical support

The next phase of the design process involved creating a learning activity prototype based in part on these key points.

5 First iteration of the evaluation prototype

This chapter describes the creation and evaluation of the first iteration of the learning activity prototype, designed to evaluate the potential of the humanoid education service robot for use in Australian primary school classrooms. As described in Chapter 4, there were various requirements related to pedagogy, alignment with curriculum content and teachers' technical preparedness that needed to be taken into account in the implementation design before this technology could be considered ready to introduce into the classroom. This chapter describes the first attempt to develop a learning activity prototype that would address these requirements as part of the implementation design. In particular, it was envisaged that having this prototype would make it possible to identify how much technical support teachers would need with the robot and what technical skills they would require to implement this technology in their classrooms. This kind of early testing was considered an important factor in the project's goal of retiring risk early in the implementation design process.

The chapter first revisits the teachers' discussion of their requirements and makes reference to relevant literature in terms of curriculum, pedagogy and teachers' preparedness to use the robot (Section 5.1). This section also describes the decision that was made to design an activity that would help primary students learn language skills. The robot's manufacturing specifications are also detailed in this section, to match its technical capabilities with the proposed use. Section 5.2 describes the construction of the prototype using interaction-based scenarios. This part of the project attempted to build some simple customised programs for the robot, in order to determine how easy it would be for classroom teachers to develop their own learning activities and lesson plans, as described in Section 5.3. Section 5.4 evaluates this process, discusses what would be further required to successfully use the robot in the classroom, and presents recommendations for the next design iteration.

5.1 Introduction

This section reports on the initial stages in the pre-implementation design process. These involved early decisions around how to design a learning activity that would evaluate the potential of the robot in light of the pedagogical, curriculum related and technical concerns identified by the teachers.

5.1.1 Pedagogy

As McKenney and Reeves (2013) note, educational design typically begins with 'large ideas', before options are constrained, mapped to a skeleton proposal and constructed and refined through prototype iteration. One of the 'large ideas' that inspired the early learning activity design for this project was based on the 'robot-as-learner' pedagogic strategy discussed in Chapter 4. The notion of children 'teaching' the robot in order to reinforce their own learning was derived from Tomasello's research into 'role reversal' in language learning (McKenney and Reeves, 2013).

Several teachers discussed how the robot could be 'a learner' and suggested that this might help students to 'take ownership' of their own learning.

> *That will be really cool if kids are able to take their learning in their own hands and teach the robot to do [something]. I think they could … teach the robot how to spell or something... They would know [then] that they can teach someone else too. (Jannie)*
>
> *Students could be creating on their own instead of being led by something I want to do. Kids should be able to take ownership and to take action. (John)*

Sometimes children learn content in greater depth if they are preparing to teach someone else (Okita, Ng-Thow-Hing, & Sarvadevabhatla, 2009). Ideas like these about the potential use of robots in education show a connection to learning approaches that emphasise creativity and problem solving (Kabatova & Pekarova 2010, Yousuf 2008).

The NAO robot is marketed as being 'suitable for multiple purposes' and 'easily customizable' (Magyar et al. 2014). In their interviews, the teachers noted that the robot could play a number of different roles in the learning process, such as teaching assistant, teaching tool or learner. Other research has shown that younger children think of robots as behaving as peers in the learning process (Shin & Kim 2007). In such cases, the robot can take the role of co-learner, peer or companion and engage in active 'spontaneous' participation (Okita, Ng-Thow-Hing, & Sarvadevabhatla, 2009) and children can learn along the way as they 'teach' it (Mubin 2013). However, older children tend to think of robots less as peers and more as 'teaching tools' (Shin & Kim 2007).

Researchers stipulate that the robot should first be properly introduced to the children, and learning can start only after the children become familiar with it. After that it can engage children with emotional expressions, natural interactions, entertainment and embodiments (Magyar et al. 2014), which may help achieve better learning outcomes (Clements and Sarama

2002). Humanoid robots can act and speak in ways that represent the canonical behaviours of an autonomous, thinking, feeling, social and moral human being. In this sense, they can be viewed as offering the same social affordances as a human and thus they can elicit the same moral considerations (Magyar 2014).

5.1.2 Curriculum

Several studies show evidence for the usefulness of this kind of humanoid robot for learning language skills. For example, English was taught to Japanese children by the Robovie robot (Kanda, 2004), and to Korean children using the Tiro robot (Han & Kim, 2009). The benefits of using robots to teach English have been discussed by computer science researchers in Taiwan, who claim that "children are not as hesitant to speak to robots in a foreign language as they are when talking to a human instructor" (Mubin, 2013, p, 2). The teachers from that study noted that the robot helped students to pronounce a word or learn certain phrases by playing a game (Mubin, 2013).

Tina, Frank, Jannie and Steve noted that the robot could be useful for teaching language skills to struggling students, who could use it on an individual basis.

> *Maybe some special students who have particular difficulties and need to do a more individualised program [would benefit more], for example maybe [students in an] English is a second language [programs], or with other kinds of difficulties … (Tina)*

> *I think it would work with kids who require individual attention consistently for learning. (Steve)*

Though the robot could potentially help students to learn language skills, research shows that "language instruction requires accurate speech recognition and that is one of the acknowledged hurdles in using robots for language instruction" (Okita, 2009, p.3, Vogt et.al, 2017). For this reason some researchers use so-called 'wizard-of-oz' techniques, where a human 'wizard' controls the robot behind the scenes to run their experiments (Okita, Ng-Thow-Hing, & Sarvadevabhatla, 2009). One study found that it was hard to reach confident validation of the robot (Mubin et. al., 2012). Given the limitations discussed in the literature around using robots for learning language skills, it would be useful to know more about best practice. Results from various studies have suggested that robots can encourage some children to improve their English and other language skills and that they may be more successful in engaging children who already know at least a little English (Kanda, 2004). Research also suggests that a robot's influence will depend on its ability to create a relationship with the user

(Kanada, 2004). Suggestions arising from this research have been that students improved their language skills with the help of robots because they had the ability to build a relationship with them through interaction and general conversation.

The teachers' thoughts around curriculum and content using this technology were mostly focused on language skills, literacy and programming. A language skill was chosen as the learning activity in this iteration process because developing a learning activity using the robot to assist in language instruction would be a valuable contribution to the curriculum. Focusing specifically on language skills helps children develop their overall literacy-related capabilities. "It is in this sense 'value added', strengthening literacy related capabilities that are transferable across languages, both the language being learnt and all other languages that are part of the learner's repertoire" (The Australian Curriculum Assessment and Reporting Authority, 2017, n.p).

John, Steve, Sarah and Tina noted in their interviews that the robot could be useful for language learning - reading sentences, breaking up words, recognising words, spelling, word sounds, structuring words and handwriting.

> *The big thing we focus on is social skills and obviously being able to read a simple sentence, so letters, thinking letter sounds, having some reading skill strategies... (Sarah)*

5.1.3 Technological preparedness

Finally, most of the teachers mentioned in their interviews their expectation that they would need professional training, time for training and preparation, and additional budget before using the robot. As described above, the initial plan involved using the teachers' responses as participatory design input to ideate how the robot could be used in the classroom. However because the teachers were not able to be involved in the project after the initial design input stage, the researcher also worked with a university-based technology development team who provided expertise in determining the level of programming ability that teachers would need to introduce the robot into their classrooms. The design of the first prototype learning activity highlighted the need to establish how best to address the teachers' concerns that:

- The robot should be able to be programmed to provide a flexible learning environment for different kinds of learning activities and different kinds of students. (This requirement related to teachers' pedagogical knowledge.)

- Teachers may need programming expertise to enable flexible / interactive use of the robot in the classroom. (This requirement related to teachers' technological knowledge.)

In their interviews, the teachers said they would like 'to be a learner first' and 'observe those who are currently using the technology tool'. They wanted to receive professional development training in this technology. They expressed a need to hold and touch the robot, and spend enough time with it to learn by trial and error. For them time to learn the technology and create new learning material was essential. Interviews with the teachers showed that they were concerned that they might be ill prepared to use the robot in the classroom. The teachers noted their expectation of receiving professional training, time for training and preparation, and additional budget before using the new technology.

Various studies have shown that teachers' training and students' benefit from using technology are closely related (Clements and Sarama 2003, Magyar et al. 2014). It seems likely that both developmentally appropriate technology and well-trained teachers are needed in school programs otherwise the interventions may be detrimental. However more research is needed to determine whether this is indeed the case and to find the right balance. Clements and Sarama (2003) have summarised research into the benefits of teacher training in relation to technology implementation. The aim of professional development activities should be to help teachers improve their technological skills, their capability to integrate technology within the curriculum, and their teaching competencies (Magyar et al. 2014). Several studies mentioned that when technology is accepted by teachers it can have positive outcomes on child development without decreasing engagement with traditional learning experiences (Mouza 2005; Clements, Nastasi & Swaminathan, 1993).

In the interviews, most of the teachers anticipated positive benefits from using the humanoid robot with their students and they believed they would have the opportunity to deliver curriculum relevant material in novel ways. They stated that all types of students would be engaged, and that the learning outcomes of students would be improved if teachers could use this technology in the right context with the right pedagogy.

Taking the above discussions into consideration led to the design of an activity focused on learning language skills where children would act as a 'student teacher' to teach the robot. Children who needed special support or were struggling with something would be able to interact with the robot individually to improve their language skills by teaching it.

Education service robots are designed to support humans rather than replace them and have a number of important features, as highlighted by Hughes (2013):

- Human interaction: The ability to perceive the environment, to learn and adapt to changes around the robot, natural embodiment through the use of legs, control of arms and the ability to manipulate objects.
- Capability to perform specific tasks: Human detection, noisy objects detection, tracking and recognition, directional speech and speaker recognition, taking pictures, and directional sound recording.
- Participation in interactive game play: The NAO robot can take part in a great variety of games with humans by identifying who speaks and understanding what is being said.

The capabilities of the NAO robots are being tested by many schools worldwide and according to the creators NAO is becoming popular for use in classrooms (Gurney, 2014). However, from informal discussions with developers and teachers who have attempted to implement lessons using NAO, it has been found that in most cases there are issues that have left the implementation in the trial phase or as training sessions only.

Humanoid robots have yet to become common in the day-to-day lives of students (unlike the iPad and other tablets). Consequently this presented an opportunity to research a technology that was new to both teachers and students. The humanoid robot appears to offer advantages over other computerised systems by allowing teachers to integrate teamwork, project management, problem solving, oral language (speaking and listening) and communication skills within a stimulating setting at school. This created the potential for us to meet a wide variety of curriculum requirements while also offering a novelty factor and opportunities for social interaction.

The idea for the case study was for children to learn language skills by helping the robot learn through games such as Simon Says, and through teaching it simple words, names and objects, etc. Such activities should encourage students to engage deeply with the material so that they can give proper instruction to the robot and to reflect on the verbal responses they receive before offering a further response.

An overview of the construction of the prototype is given below. A detailed description of the development of the learning activity will follow in Section 5.3.

5.2 Construction of the prototype

In this first iteration, the fully functional prototype for implementing a learning activity was designed to gain an understanding of the best ways to use this robot in an educational context and of teachers' preparedness for this technology. Agile methodology was used so that the teachers would see early mitigation of any technological or implementation risk. University developers and programming technicians provided support for this stage of the project. The researcher worked directly with the university development team by attending face to face weekly meetings, discussing technical issues related to implementation, and offering flexibility to change requirements if needed.

The programming languages used for development were Python and AIML (Artificial Intelligence Markup Language). Python is the default language of Choreographe (which is used for the visual programming of the NAO robot), so in order to keep things simple this was the main language used. AIML was used for the 'conversational' part of the project. It was a project prerequisite that the university developers already knew these languages. They also had prior experience in programming a robot. The researcher worked with them to determine how much support the teachers would need for ongoing development of this system (see discussion below).

5.2.1 The initial learning activity design

The next step in developing the learning activity was to assess the capacities of the NAO robot and to detail the functional requirements of the system. The learning activity was designed to have the robot interact with a child learning a language skill. The robot was to take the role of a learner and create a reflective role for the child as they instructed the robot learner on what they themselves had already learnt. The plan was that as a learner, the robot would utilise many of its capabilities including visual object recognition, human face recognition, gesture recognition, natural language processing and physical decision-making. The ability to do these human-like tasks enables the robot to also play games, such as 'Simon Says'.
There were four distinct skills for the robot to cover, each a set of one-on-one interactions between child and robot. Children who required special assistance in language skills were the target group for this study and they were expected to actively participate in their learning by instructing the robot on the following topics.

- **Topic 1: Elements**: basic letters/ alphabets
- **Topic 2: Components**: words, names, objects and pictures from flash cards.

- **Topic 3: Compounds**: sentences, context and grammar.
- **Topic 4: Game play**: turn-based interaction using the elements, components and compounds topics. An example is the game 'Simon Says'.

Learning objectives

There were to be two separate learning activities. One covered Topic 1 and Topic 2 and was targeted at children in prep to grade 2. The children were expected to learn the alphabet, names of objects by recognising pictures, and spelling and pronunciation by teaching the robot.

The second learning activity involved Topics 3 and 4 and was suitable for Grade 3 to 6 children. They would learn sentence construction, grammar and play a 'Simon Says' game with the robot.

The teachers thought that the number of sessions planned for needed to be flexible so that each child could spend time on each topic based on their individual learning needs.

5.2.2 Functional requirements

A number of functional requirements were collected and identified for the implementation of these language skill activities. The requirements covered not only the robot's capabilities but also the support system that the robot talks to, and the human research supervisors who would be monitoring the interaction at all times. Some of the functional requirements are:

- **Recognise and remember letters, words, faces and objects**: For example the robot needs to be able to learn the alphabet from its student teachers and remember the name of each student.
- **Initiate and lead a conversation with expression and emotion**. For example, the robot should be able to sound human and have a friendly tone and manner.
- **Follow and continue a basic dialog**. This would be required for simple game play (Simon Says).
- **Walking while avoiding objects and falls**.
- **Pick up, manipulate and place objects**.
- **Detect (locate), track and focus (head movement) on a person using audio and video signals**. This can be extended to identification of the subject's body position (pose) and tracking change (movement).
- **Memory (database) of the interaction session**. As the robot learns from the student teacher the data needs to be stored and accessed to enable sensible interaction.

- **Adaptive scripting for interaction session**. Essentially the interaction should be scripted to follow a standard form, but also be robust and flexible enough to handle the natural variation of human interactions. This would be supported by researcher supervised monitoring and override control if needed.
- **Remote recording and operation**. Ideally the student teacher would be able to interact with the robot without excessive interference from a supervisor or researcher.

5.2.3 Features and Possible Interactions

A learner (the child) was placed in the position of teacher, a role referred to as a “student teacher”, which would create a need for the student teacher to reflect on their own recent learning in order to teach. The intent was that the student teacher’s level of understanding would be assessed before and after the learning interaction with the robot but in the end this did not happen in this iteration.

The basis of these iteration processes was to research how the robot could be used in the classroom. With this in mind, the teachers were shown the four topic descriptors and asked if they could identify any foreseeable concerns they might have with either the technology or the requirements for interacting with the technology. None were identified and the teachers were in agreement that these would be useful activities, that they met curriculum requirements and that the children would benefit from enabling multiple repetitions.

Topic 1: Letter and Number Recognition

This stage involved teaching the robot to recognise the basic letters and numbers. Letters and numbers were provided on flash cards to make the task technically robust. Note that the student while acting as the teacher is referred to as “student teacher” in these dialogues.

Student teacher: “I want to teach you a letter.”
Robot: “Okay. Please show me the letter.”
Student teacher: Selects a flash card with a letter on it. Holds it up for the robot to see.
Robot: Moves head to track the flash card.
Robot: When letter identified says, “What is the letter?”
Student teacher: “It is the letter ‘A’.”
Robot: “A”
Student teacher: “Yes – that's it!”
Robot: “I think I know it now. Want to test me?”

Student teacher: "Well done!"

Topic 2: Words, Names and Objects

Building on the outcomes of Topic 1, the aim of this stage was to learn words, names and other objects. Once the robot has been taught and has a working database, it can be questioned about what it knows. If movement and object manipulation is technically robust at this stage it could also be incorporated.

Student teacher: "What colour is a strawberry?"

Robot: "It is red."

Student teacher: "That's right. Can you find something that is red?"

Robot: "I'll have a look". It searches for a red object and turns body until it finds a red ball. It walks to ball, picks it up, and returns to the previous position.

Student teacher: "Can I have it?"

Robot: "Yes". Offers the object with an open hand.

Student teacher: "Well done!"

Topic 3: Sentence Construction, Context and Grammar

Extending Topic 2, this stage could involve specific lessons and interaction about the structure of a sentence. For example, the student teacher could teach and ask the robot to identify parts of speech in a sentence. The dialog to support this (example omitted for brevity), while still structured, requires a strong internal model for learning within the robot's programming.

Robot: "Let's do some grammar now. Give me a sentence problem"

Student teacher: "Listen carefully to the sentence: I have a red ball."

Robot: " What do you want me to do with the sentence?"

Student teacher: "Find noun and pronoun from that sentence."

Topic 4: Game Play

For the planned research objectives, game play creates an excellent opportunity for interaction and engagement between student teacher and robot. Initial planning and development focused on implementing the well-known game 'Simon Says', where the robot is able to perform the role either of 'Simon' or of a follower. This requires not only the ability to carry out and understand a dialogue with the human student teacher, but also to interpret the body position of the human. The robot also needs to be able to apply the rules of the game in a meaningful and robust manner.

Student teacher: "I want to play Simon says."

Robot: "Do you want me to be Simon or do you want to be Simon?"

Student teacher: "I want to be Simon."

Robot: "Okay, I'll follow what you say."

Student teacher: "Simon says 'Raise your left hand'." (Robot lifts its left hand).

Robot: "Did I perform the action correctly?"

Student teacher: "Yes. Well done!" (Robot dances.)

During all the interaction sessions, data learnt by the robot is stored in a database. Observations and decisions made by the robot are recorded for analysis.

5.3 Results of the prototype construction

There were many issues and challenges that occurred during the development and testing of the prototype, as well as some pleasing outcomes.

From the description and basic tutorial on Choreographe it was considered that the tasks set for programming the robot for this project were achievable. The development team and their research team 'clients' attempted to ensure that the given specifications and standard usability practices were adhered to and that the design met the first round of user requirements. The software development was undertaken as though the development team were starting with zero knowledge of the robot and its capabilities. This included no knowledge of how to set it up nor of the software Choreographe that is used to run the robot. It was felt that this was essential to simulate the classroom teacher's first introduction to the technology and the software.

5.3.1 Programming skills required

The initial interaction with the robot using Choreographe was quite basic, as it was simple and obvious how to make the robot move and show it waving, talking, dancing etc. The visibility of the system was obvious, in that instant feedback was received by the movement of the limbs or the verbal response given as each runtime occurred. The icons used to represent actions were self-explanatory and they were dragged and dropped into the workspace where a progress path was then created using a connector to link the actions. The actions available were not in any order, which was a time waster for the team just as it would be in a classroom if searching were required. Overall it was easy to do the most basic of pre-programmed activities. The level of difficulty for a non-programmer occurred after this stage.

The descriptions below rate the various levels of programming skills that were required to achieve actions or interactivity with NAO. This is to demonstrate what a teacher would be able to achieve for their classroom depending on their programming skills.

Level 1:

Before commencing the development of the full planned interactions it was necessary to learn how to program Choreographe to make NAO undertake each of its individual actions. This included such actions as verbal responses and going through a dialogue with prepared prompts, decision making and iteration, teaching the robot to recognise shapes, walking, picking up items, facial recognition and movement of limbs. All of these were easy enough to teach NAO in isolation using the easy to use Choreographe tool kit. It was simply a case of dragging the appropriate action from the library and attaching the required dialogue and activity path.

Level 2:

The next level involved setting conditions and loops, which required a knowledge of programming practices but not necessarily coding skills. Conditions needed to be set for the robot to recognise objects or people, and to know how to respond to inputs, for example which limb to move to mimic a movement. Repetitions occurred when the robot searched for another item from a list of actions for example. However, it was possible to set conditions for these activities without opening the source code and editing as there were built-in selectors to set the number of repetitions, conditions etc.

Level 3:

A level of difficulty was identified when the developers attempted to combine actions into a flowing interaction that offered the affordance of a human interaction. This level of programming required the user to edit the source code or to write small routines that would enable 'out of the box' activities or combinations of activities that were reliant on previous conditions. Depending on the activity this might require anything from basic coding skills to quite extensive coding skills.

5.3.2 Things that went wrong

Setup

Connectivity was an issue as the robot needs a Wi-Fi connection to a laptop. The connection was often lost and the robot required assistance from technical support to reconnect each time. Eventually after quite a bit of research it was found that a separate router provided the stability required for a continuous reliable connection. However configuring the router also requires input from technical support.

Balance

Balance was an issue with any movement such as raising limbs and walking on surfaces like carpet and some vinyls. This made it necessary to look at minimising movement and selecting floor coverings that could be rolled out for the demonstration. This is a consideration in classrooms with carpet on the floor.

Speech

During the 'Simon says' game the robot often did not recognise the natural speech of the user. NAO has limitations in its built-in speech recognition and it requires a list of words to be input to use as a comparison. Various combinations of words and the speech recognition box were tried but the Choreographe software could not handle the resulting lists adequately. Initially to overcome this the users were required to speak very loudly and clearly and to ensure that they only started talking after the beep as anything said before the beep was not "heard" by the robot. This still led to many misinterpretations. If the robot did not respond it generally meant that the voice level was too low and the user had to repeat what was said. The next work around for this was to employ the Google Chrome Web Speech Recognition API which is a built-in function in the Google Chrome browser. This did increase the word recognition but still did not really enable free flowing natural speech.

Once the 'Simon Says' game started, the robot would ask if 'you want to be Simon' or if 'you want me to be Simon'. In this case the robot was programmed to listen only for the words "me", "I" and "you", to increase versatility. So a response had to include one of those words e.g. "I want to be Simon", "make me Simon" or "you be a Simon". These phrases all make perfect sense to a child but they are not suitable to initiate an action from the robot. Phrase variations such as "I would like to be Simon" instead of "I want to be Simon" are misunderstood if the robot is looking for whole phrases to recognise. To make the robot understand a wider variety of phrases, which helps reduce the feeling of a scripted conversation and allows the conversation to feel more natural, 'word spotting' was used. This finds certain words in what was said and the robot then reacts accordingly.

The study also found that:

- Using word spotting so that the words “I”, “me” or “you” all provided the same response from the robot irrespective of where they appeared in the phrase used by the child was effective and very robust. It caused more misunderstandings than requiring a set phrase but the robot could now understand a far greater variety of phrases.
- It is beneficial to offer alternative words for the same action. For instance when the child did not want to continue they could say either, “no more”, “stop”, “enough” or “no” and any of these would end the game, while anything else would start another round.
- The learners will need to be supplied with lists of words and phrases that are understood by the robot. For our project the list included phrases such as “raise your right hand”, “raise your left hand”, “look to your left”, “look to your right”, “crouch”, “both hands up”, “wave”, “turn around”, “point left”, “point right”, “moo like a cow”, “go to sleep”, “swing your arms”, “pat your head”, “click your fingers”, “dance”, “play air guitar”, “play air drums”, and “sing”.
- If users paused too long within their sentence when talking to the robot, the robot would think that they had finished talking and would only interpret the first part of what was said. This was especially relevant in ‘Simon Says’ where the user frequently paused after saying “Simon says” and before giving the instruction.

From interviews with other developers it was found that issues regarding normal speech are common with the NAO and often lead to presenters reverting to “Wizard of Oz” style demonstrations, where the robot’s voice response to the child’s conversation is directly manipulated by a programmer. This can be seen in many public demonstrations of humanoid robots where the interaction appears to flow in response to casual conversation. It happens especially in demonstrations involving children where they may not stay on topic, never mind remembering to use a limited vocabulary in their conversation.

Performance issues with software

There were performance issues when first opening the ‘Simon Says’ files. There were too many action boxes, which caused Choregraphe, and thus the robot, to give no response or feedback for a few minutes. This would cause issues within the classroom context.

Unrealistic Expectations arising from Wizard of Oz demonstrations

It is understandable that humanoid robots are thought to be a 'walk up and use' technology. This comes not only from the developers and the media, but generally the affordance of human behaviours creates an expectation of intelligence and reasoning in robots rather than that they are just responding to developed instructions. Interacting with the robot looks very easy in the manufacturer's promotional media. However the dialogue is scripted and has had many hours of work behind the scenes to make it look as though it is a natural free flowing interaction. Further, the videos have been cut and pasted to appear fluid, just as ours were when we gave presentations on our progress. None of this assists in setting a realistic view of the real usability of robots for non-programmers or non-technical users, and can create unrealistic expectations from schools, parents and teachers.

5.4 Discussion

The main goal of this research was to gain an understanding of what is necessary to support a teacher who undertakes to include an emerging technology in their classroom activities. In particular, this study looked at the expectations of the emerging technology around humanoid robots and the realities around their use as a classroom learning tool.

It was found in this study that the way humanoid robots are portrayed in the media means that users expect them to be an easy to use, almost infallible technology (Curtis 2012). On top of the media hype, the fact that the robot is humanoid furthers this belief in that it appears to have human characteristics and creates a mental model that matches the expectations of a human or small child (O'Donnel 2012). This includes the ability to learn and reason through normal verbal and physical interfacing rather than through a computer terminal. From this expectation it seems reasonable that the inclusion of a tool that will engage children’s imagination, undertake repetitive tasks and be totally non-judgmental of failure would be seen as an asset to the classroom (Robins et al. 2005).

From discussions with others who have deployed or attempted to deploy the humanoid robot in the classroom and from the outcomes of our attempts to build a near foolproof, easy to use, interactive lesson based on the robot’s capacities, the conclusions regarding deployment in the classroom can be summarized as follows. These conclusions are for the average classroom teacher without a programming background.

Level 1:

The pre-programmed actions from Choregraphe achieved after a basic level of training. Included setup of wifi connection (although not reliable) and drag and drop pre-programmed actions.

Support required: Basic training, technical assistance prior to setup and during session for resetting if connection lost. Ensure non-slip surface for the robot.

Expected Training: Approximately 4 hours to familiarise with connection and actions.

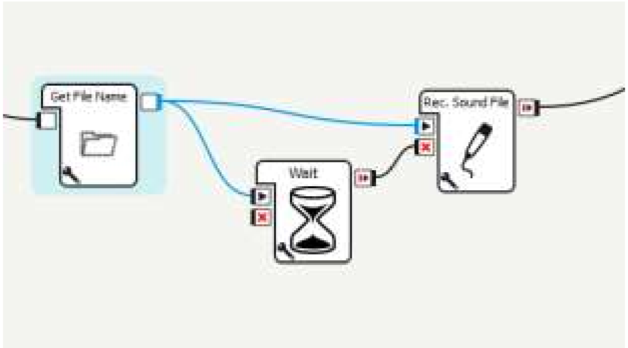


Figure 5.1: Words: Reading Handwritten Words

Level 2:

Simple interactions can be achieved where basic pre-programmed actions are linked

Support required: As per Level 1 but with further training to explain some basic programming practices such as conditions and loops. Further training may be required of the technical assistant or teacher to cover the exceptions that may occur.

Expected preparation: Approximately 40 hours for the initial 1 hour lesson, approximately 2 hours for each 1 hour lesson after the first.

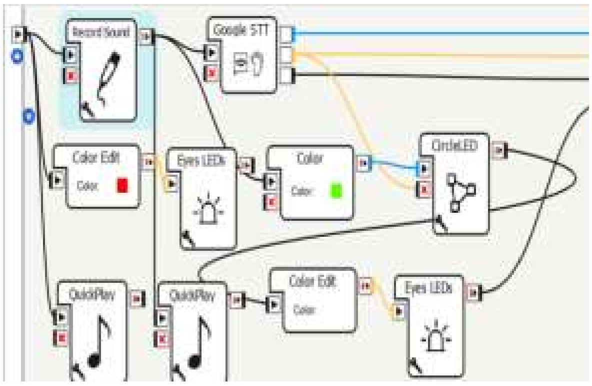


Figure 5.2: Words: Verbal Speech to Text

Level 3:

Advanced Interactions enable fluid conversations and activities often associated with a “thinking” humanoid robot.

Support required: The project did not reach this stage and anecdotal evidence suggests that many others have not either but have improvised along the way to give an impression of the human aspect of the robot. This level requires substantial programming and testing for the variety of situations that can occur in the classroom.

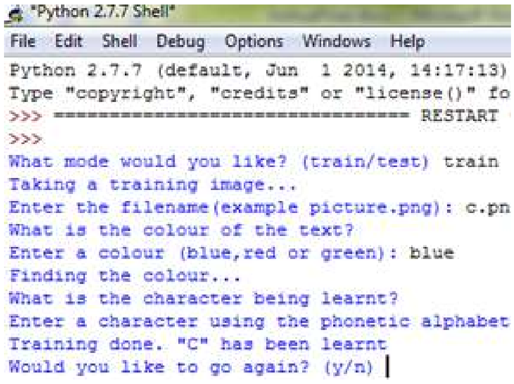


Figure 5.3: The python code for the NAO robot

As has been identified by other researchers, it is very difficult to meet the expectations caused by the human aspect of the robot and to create responses for all possible scenarios or discussions. It is the opinion of this researcher and others who have trialed the robot that in order for an activity to be fit for presentation to students there must be input from a development team, technical support within the school to ensure ongoing connectivity, a teacher to work alongside the children and a suitably tested physical space where the robot is to be used.

Even for the simple exercises associated with this project the time outlay was substantial, but what was more of a concern is that for all the topics attempted the software was not suitable to allow a non-programmer teacher to competently perform any of the tasks without assistance or intervention. This is not to say that better, more stable software cannot be written nor that more reliable connectivity cannot be established, only that the customisation of programs to suit individual needs is not as simple as it appears in the manufacturer's demonstrations.

It is understandable that humanoid robots are thought to be a 'walk up and use' technology. This comes not only from the developers and the media, but generally the affordance of human behaviours creates an expectation of intelligence and reasoning in robots rather than that they are just responding to developed instructions. None of this assists in setting a realistic view of the real usability of robots for non-programmers or non-technical users, and can create unrealistic expectations from schools, parents and teachers.

Risks and limitations

This prototype was not tested with children because of the risks and issues identified during construction of the prototype. The robot was simply not flexible enough to perform the curriculum-based activities chosen. So the next iteration, discussed in the next chapter, sought to identify a more suitable classroom activity that this robot could support and that required less preparation from the teacher.

5.5 Conclusion

The curriculum in primary school education offers many opportunities for the introduction of technology that can offer a novel interface with students and provide a human-like face to a technical interaction. What the current capabilities of the robot offer is the opportunity to discover, learn logic, basic programming techniques, communication, group work and many other computational skills, as seen in the example of the second-graders at the Northwoods Elementary School of Technology and Innovation in Onslow County, North Carolina (Curtis 2012). The imagination and problem solving, trialing and refining the interaction, and a renewed enthusiasm towards computer science are valuable skills, knowledge and attitudes that make the use of NAO and other robots seem worthwhile even in these still early stages.

However, teachers and students should know that there is a lot of support and knowledge needed to get the robots to do what they are expecting and the lack of ease of use may currently take the robots beyond what could be expected of the non-tech, non-programmer when it comes to activities that require fully interactive capability on the part of the robot. The main concern with the expectations that are created by such emerging technologies is that they are expected to be an “easy add-on” to the teaching tool kit. This stage of the project found that not to be the case. Before teachers and schools invest both time and money in equipping their schools and classrooms with these kinds of educational tools, schools will need to ensure that teachers are well supported in their attempts to use and experiment with them.

In this case, the robot was not easy to fit into curriculum-based activities to develop language skills because it requires an advanced level of programming expertise to make the robot interactive enough to fit into these linguistically challenging activities. This would be difficult even for teachers with advanced programming skills.

Various issues were identified in constructing this initial prototype. The robot is not flexible enough for the proposed learning activity. Teachers require advanced programming expertise with a large investment of time needed for professional training and to practice this technology. Teachers also require technical support to use this technology in the classroom. The Agile method was used intentionally to identify risks and issues in the early stages, so the next iteration is again construction of a prototype to implement a learning activity but this time one that is more suited to this technology and where teachers only require a basic level of training and programming expertise to make the robot fit into the curriculum.

Chapter 6 describes the process of redesigning the learning activity based on what was learnt from the first prototype. Even if it is difficult to adapt the NAO to assist with learning language skills, there may still be other opportunities to use the NAO in the classroom for teaching computer science instead, given that this is fast becoming a core in many curriculums. This suggestion resonated with most of the teachers in the study and it will be explored in detail in the following chapter.

6 Iteration 2: Using the robot to teach programming

This chapter presents the second design iteration in the pre-implementation evaluation of the education service robot. The first iteration involved designing and testing a language learning activity (Chapter 5) to form the basis of the rest of the evaluation process. Chapter 5 showed how design methodology can be used to identify and retire risk early in the pre-implementation process. It revealed a substantial risk in that teachers would require an advanced level of programming skill to develop and implement the language learning activity using the robot. From this, it was seen that the first iteration would not satisfy the technological knowledge (TK) design requirements set out at the end of Chapter 4. This also meant that it would not satisfy the first of the pedagogical knowledge (PK) design requirements, as teachers would not be able to readily continue to re-program the robot on an ongoing basis to provide a flexible and adaptive learning environment to suit the language development needs of a wide range of students.

After the evaluation process described in Chapter 5, the decision was made to switch from the design goal of using the robot to teach language skills to that of using the robot to teach programming skills. It was considered that this change in the design would make more realistic demands on the teachers' levels of technological expertise (their TK). It was also thought that this change would have a range of implications in terms of both curriculum alignment and pedagogy (related to the CK and PK requirements presented at the end of Chapter 4), and this proved to be the case.

6.1 Introduction

As noted in Chapter 5, the educational service robot has a library of standard behaviours and its Choregraphe programming software has a graphical interface that allows users to create and edit movements and other interactive behaviours. Robot behaviours can be created by dragging and dropping actions from the library or creating customized boxes and saving them to custom libraries. Users can explore programming by sequential or parallel events. Regarding chronology, Choregraphe allows users to program using sequential logic. These features suggested that the humanoid robot could be used to teach programming to primary school students (Chen et al., 2017) and all the teachers interviewed referred to this possibility, mainly in their comments related to ‘curriculum’ and ‘skills’ (Chapter 4).

These responses on the part of the teachers may reflect a recent increasing emphasis on embedding computer programming into the Australian Curriculum from a primary school level. The impetus to teach programming is being driven by various factors, including economic responses to technological advances (Department of Education and Training, 2015) and the demand for a future workforce with the necessary digital literacy (Australia's Future Workforce, 2015). In Australia, there has been a governmental level push in STEM education (Australian Industry Group, 2013). Australia's Chief Scientist Ian Chubb has claimed that introducing computer programming in primary schools will contribute critically to this 'future workforce' initiative since children's early experiences are a likely factor in their persistence in the STEM domain and their future career choices (Chubb, 2015; Australia's Future Workforce, 2015). Calls to introduce programming skills to children early in their education have been reflected in curriculum changes in many countries. Many European countries have computer programming in their curriculum (Kotsopoulos et al., 2017, p. 8). Countries in various Asia-Pacific regions are in the process of including programming in the curriculum (Microsoft APAC News Center, 2015; Bell, Andreae & Robins, 2014).

Programming concepts have already been introduced into the Australian Curriculum for Digital Technologies for primary aged children (Australian Curriculum, 2017). The curriculum proposes that children can develop the concept of abstraction by defining problems, gathering important data with relevant steps and summarising facts. Years 3 and 4 children can plan a sequence of steps using an algorithm to solve a problem using visual programs rather than a text-based programming platform. Years 5 and 6 children can plan, design and provide a solution to a problem by following simple algorithms involving sequences of steps, branching, and iteration or repetition using visual programming. The Queensland Government in Australia claimed that it was "committed to making sure that every student will learn the new digital literacy of coding and have the opportunity to apply these skills through robotics from 2016" (Department of Education and Training, 2015). Victoria, too, will embed coding in its curriculum from 2017 (Victorian Curriculum, 2017).

The terms 'coding' and 'programming' are sometimes used interchangeably in the literature; however their meanings differ. Although the word 'coding' is widely used, it more accurately refers to a skill needed for computer programming (Duncan et al., 2014). Learning to 'code' may only involve learning to follow 'programming expressions', and learners "may only be taught to take existing code or pseudo-code and enter it themselves" (Duncan et al., 2014, p. 61). Programming, on the other hand, involves many other skills, such as establishing specifications, planning and debugging. For the purposes of this study, the term 'programming' will be used for skills learnt that allow students to plan and design, to analyse a problem and implement a computational program that solves it. All of this is not necessarily in a user's mind when they use the word 'coding'.

Along with the inclusion of computer skills in K-12 curricula, recent years have also seen a major focus on programming pedagogies. Much of the research in this arena has drawn on constructionist approaches to education initiated by Seymour Papert (1980), the 'founding father' of educational robotics (Catlin & Woollard, 2014). Papert studied under Jean Piaget, who introduced constructivism, exploring how children learn by 'constructing' mental representations (Papert, 1980). Papert went on to develop the notion of a 'transitional object', proposing that ideas arising from children's imagination, emotions and experiences could be transformed into 'tangible' objects, helping them to create thinking patterns in which mental structures would emerge (Papert,1980; Catlin & Woollard, 2014). Researchers focusing on the use of robotics in early education drew on Papert's pedagogical approach, in particular the DevTech research program at Tufts and MIT Media Lab/Harvard collaborations (Flannery & Bers, 2015; Brennan & Resnick, 2012)

More recently researchers have suggested that children can learn computational thinking (CT) (Wing, 2006) using constructionist approaches and it has been claimed that there is a strong correlation between the ideas of CT and the principles of Papert's educational robotics (Catlin & Woollard, 2014). Researchers have proposed that learning activities using robots form a 'natural symbiotic relationship' with CT and that educational robots offer 'tried and tested' ways to develop CT as part of K-12 education (Catlin & Woollard, 2014).

Programming also has a close relationship with mathematics and mathematical concepts are used in introducing a set of arithmetical operations to a computer and determining solutions.. According to Schwartz (1969), if a programming language is designed "on finite sets and functions on sets in a manner that was true to the mathematics involved, then the language would develop into something that could express the most complex mathematical relationships in a manner that added little or no difficulty to what was already contained in the mathematics" (cited in Dubinsky, 1995, p.1027).

The introduction of functions means constructing abstractions of CT by offering complex problems. Papert (1972, 1980) noted that writing programs with Logo turtle was a new part of geometry which offered clear discussion and "a simple model of heuristics such as debugging" (cited in Pea and Kurland, 1984, p.142). Logo's 'turtle geometry' allows students to manipulate the on- screen 'turtle' to draw various shapes using the programming software application

(Schanzer, 2015). Ross and Howe (1981) described the expected benefits of learning programming, claiming that programming motivates students to study mathematics, including the mathematical concepts, key insights into specific concepts, and justification of formal mathematical formulae.

CT is an analytical approach that has points in common with mathematical thinking; in general it involves solving problems and designing systems (Wing, 2008). Wing initially defined CT as entailing abstraction (identifying problems at various levels of detail), algorithmic thinking (breaking down tasks into step by step small tasks), decomposition (solving problems partially) and pattern recognition (finding a new problem that can be related to the previous problems) (Kotsopoulos et al., 2017). CT's concepts and practices mainly derive from computer science, but many of its ideas are shared across other disciplines areas. According to Wing, CT should be "added to every child's analytical ability" (Wing, 2006, p. 33).

Recent strong interest in CT has influenced many educational authorities worldwide and CT has become a curricular expectation in various countries (Barr & Stephenson, 2011). For example, England has introduced 'coding' as an example of CT that is part of a mandatory national curriculum area in elementary schools (Duncan, Bell, & Tanimoto, 2014). Changes to K-12 curriculum to include programming have also engendered debate on the appropriate age for the introduction of a range of programming concepts (Barr & Stephenson, 2011; Duncan, Bell, & Tanimoto, 2014). Commentators have proposed that educators should not wait until post-secondary education to introduce CT, but that CT concepts should be introduced into primary (elementary) level classrooms (Barr & Stephenson, 2011).

Despite the increasing popularity of CT, recent research has also involved criticism, mainly in terms of how it can be rigorously defined and whether it is transferrable across domains of learning (summarised in Tedre & Denning, 2016). In terms of its definition, there have been arguments that CT should be viewed as a set of skills rather than as "a particular set of application knowledge" based largely on mathematics (Tedre & Denning, 2016). A skill can be defined as an ability that children can learn over time with practice, not merely knowledge of facts; most of CT as it was initially conceived, however, involved a body of knowledge about abstract concepts and mathematical procedures for manipulating these. Tedre and Denning (2016) identified a new wave of CT focused not on measuring students' knowledge, but instead their competence. They based this proposal on findings that students who received good scores on tests and were able to explain and illustrate abstraction and other high-level programming concepts could still be seriously lacking in competence in computation (Tedre &

Denning, 2016). Tedre and Denning related their study to Polanyi's research into 'tacit' dimensions of expertise, citing Polyani's claim that highly skilled practitioners "know more than [they] can say" (Tedre & Denning, 2016).

Brennan and Resnick also showed in their analysis of interviews and observation of young children that framing CT as based on 'concepts' does not sufficiently represent the full range of elements of computational learning (Brennan & Resnick, 2012). Accordingly, they created a new framework giving equal weight to 'computational practice' and 'computational perspectives', along with the previously articulated knowledge-based set of CT 'concepts'. Brennan and Resnick's research into computational practice has emerged from their interest in exploring the 'habits of mind' developed by young programmers. As they note, CT needs to articulate computational practices by observing how children engage with technology creatively while achieving outcomes driven by their own interest (Brennan & Resnick, 2012).

In addition, many key aspects of CT as it was originally conceived seemed to be beyond the cognitive development of very young children (Duncan et al., 2014); in particular, the principles of logic and algorithmic problem solving central to conceptualisations of CT are not usually introduced before the upper primary levels of schooling. However the emerging emphasis on computational practice draws on the decades of research into robotics education described in Chapter 2 showing that very young children can develop their computational literacy using robots (Flannery & Bers, 2015).

The notion of computational practice as a component of CT has given rise to several frameworks that define important aspects of computational development in terms of 'doing' rather than 'knowing' (Tedre & Denning, 2016). As well as Brennan and Resnick's (2012) 'Scratch' programming framework, described above, Kotsopoulos et al. (2017) developed the Computational Thinking Pedagogical Framework (CTPF) to guide teachers of ICT in their training and professional development. Like Brennan and Resnick's framework, the CTPF was inspired by constructionism (Papert, 1980, 1987; Papert & Harel 1991) and theories of social-constructivism (Vygotsky, 1978). The CTPF contains four pedagogical 'experiences': unplugged, tinkering, making, and remixing (see further discussion in Section 6.5).

The framework for CT evaluation used in this thesis was developed by 'Barefoot Computing' (Csizmadia et al., 2015). Csizmadia et al. (2015) typology of CT provided a 'lens' for the observation and classification of how students interacted with the educational service robot in the course of the learning activity. As shown in Figure 6.1, the Barefoot Computing model divides CT into 'concepts' and 'approaches', which correspond to the 'knowing' and 'doing' categories described above.

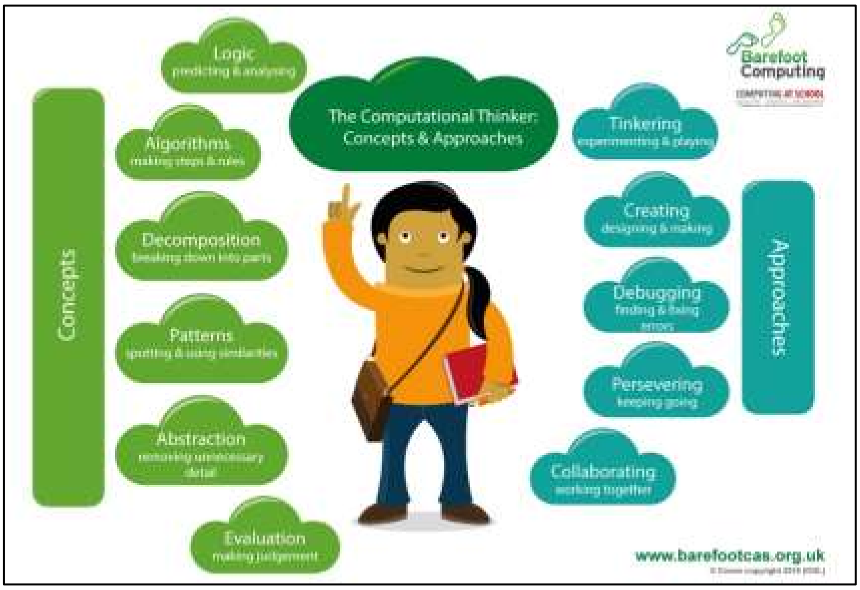


Figure 6.1: Thinking concepts and approaches of CT proposed by Barefoot Computing, 'The Computational Thinker' (Csizmadia et al., 2015, p. 8)

Because this study investigated primary school children, it was thought that these five 'approaches' would provide a more relevant way of evaluating outcomes of the learning activity, especially among five to eight year olds, than trying to measure their output in terms of traditional CT cognitive markers like 'logic' or 'abstraction'. A decision was made, therefore, to evaluate 'approaches' as instances of computational practice. Another advantage of doing this was that computational practice conceptualised in this way manifests as behavior that can observed and evaluated in children without pre/post testing (Chen et al., 2017), and it can then be mapped to competencies derived from a computational practice framework for assessment purposes (Brennan & Resnick, 2012).

The five 'approaches' originally proposed for this study were (Csizmadia et al., 2015):

- Creating: Programming can be a creative learning process for children as it involves engaging in purposeful activity to produce something original and valuable. This approach is mainly observed when children are encouraged to reflect on the quality of their work rather than just on the goal of achieving the 'right' sequence of actions.
- Debugging: Programming is complex; therefore, programmers often write codes that do not work as intended. The debugging approach is observed when children start thinking through their code, and working to identify and fix errors. This is an important part of learning programming—identifying mistakes, making suggestion for fixing

errors and making improvements. Children can debug their own or another person's code.

- Collaborating: Collaborative work is already emphasised in primary schools. When learning to program, children can share a screen and a keyboard when planning and writing codes, swapping their roles, sharing their ideas, and discussing them together to solve a problem/create something effective.
- Tinkering: Tinkering involves exploring and playing with new things. Tinkering implies a willingness to independently explore new tools, software, hardware or other materials.
- Persevering: Because of the complexity of computer programming, writing effective code is challenging for children. Persevering involves being willing to preserve with something that is difficult and that can cause frustration. This approach is observed when children keep going with their work even in a difficult situation, not giving up, and being determined to search for the solution of a problem themselves. It can also involve asking for help from friends or an instructor rather than giving up.

This chapter describes how 37 children interacted with a humanoid robot in a learning activity designed to help them develop skills in computational practice. The prototype learning activity was tested in a controlled environment using video methods to collect data. The study aimed to identify what kinds of learning the robot could support in relation to the curricular emphases described above. It also aimed to identify further links with the teachers' pedagogical and technological knowledge described in Chapter 4.

Section 6.2, below, describes the study design, followed by the results in Section 6.3 and discussion and concluding remarks in Section 6.4.

6.2 Study design

This section describes the methodology used to further iterate the prototype learning activity, to adapt it to teach programming with the robot and to evaluate it. As noted in Chapter 5, the researcher drew on her own teaching experience and educational expertise in designing the activity, as well as using the teachers' responses detailed in Chapter 4 to provide further input to the design of both the revised learning activity and the revised objectives of the observational study.

As well as redesigning, testing, evaluating and refining the learning activity, the sub-aims of the observation and analysis phase described in this chapter included establishing its target age group, deciding whether it would work best in terms of group or individual activity, and refining criteria related to its learning environment and proposed students' learning outcomes. These categories were chosen on the basis of the teachers' earlier input into the possible use of the educational technology and the capacity and expectations related to the kind of student cohort who would work with it in the future (Chapter 4). It was not possible to address all the teachers' suggestions in designing a single activity; therefore priority was given to the most tenable requirements.

The main curriculum focus in the next iteration of the learning activity involved 'learning the basic concepts of programming. As the teachers had noted, it seemed likely that students would be interested in 'how the robot works' from a programming perspective.

Other design revisions suggested by the teachers' input related to:

- Group size: The teachers thought that learning activities using the robot could cater to individuals or small groups. Because Csizmadia et al. (2015) had proposed 'collaboration' as one of the five 'computational approaches', it was decided that the revised learning activity would need to be designed with collaboration in mind, meaning that it should incorporate group-work. In this phase of the study, therefore, small groups of 2 and 3 at a time were trialled to investigate optimal group size.
- Age Groups: The teachers had thought that the robot could be used with primary school students of 'all ages'. The study therefore recruited children in Grades Preparatory (Prep) to 6 to observe and evaluate their reaction to the robot in the context of the learning activity.
- Student independence: Some of the teachers had recommended that students should be able to take 'ownership' of their learning and that the robot could be used to facilitate this. The learning activity was therefore designed so that after first experiencing an introduction given by the facilitator, the students could work on the learning activity independently, furthering their own self-direction and learning.
- Teacher training and preparation: The findings described in Chapter 5 suggested that the need for teacher training and technological pre-preparation should be kept to a minimum; this was done by using pre-programmed routines in the redesigned learning activity and allowing the students to then undertake learning by discovery.

Using these recommendations, the project was redesigned with the aim of using the humanoid robot to engage the children in a learning activity designed to stimulate their computational skills.

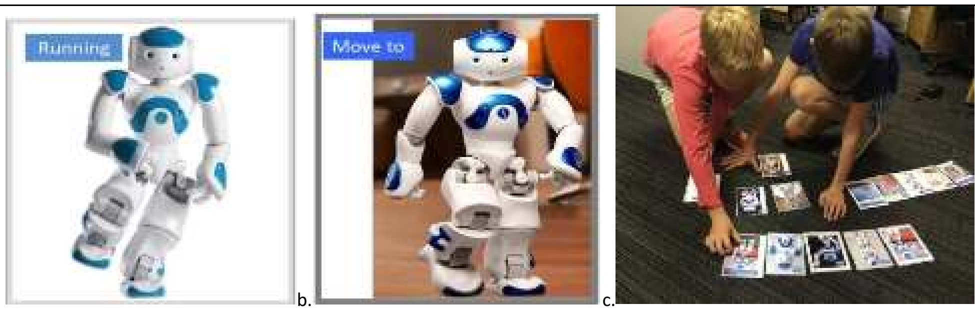
6.2.1 The redesigned learning activity

Chapter 5 described the language skills based learning activity that was first developed. However evaluation of this activity showed that teachers' programming expertise would need to be considerable to meet its pedagogical requirements—in particular, the need for the robot to meaningfully 'converse' about language. The learning activity therefore had to be redesigned to mitigate this risk. The new design still took into account constructivist learning (Piaget, 1985), but switched from language skills to computational practice in terms of its curriculum alignment (Brennan and Resnick, 2012). Moreover, focusing on the relatively recent goal of enhancing computational practice using robotic technology meant drawing on pedagogies related to deep constructionist learning (Papert, 1993).

Using constructionist learning principles entails encouraging children to engage with technology in very physical and exploratory ways. The decision to adhere to these principles meant that the activity would not have to rely on back-end 'Wizard of Oz' programming strategies but could instead be designed to encourage children to program the robot for themselves. Teachers would only require a basic level of programming to develop such learning activities. Constructionism also stresses 'participatory' learning, so this also fitted with the teachers' pedagogical emphasis on collaboration in their classrooms.

The four stages of the activity were:

Stage 1 (10 minutes): In each session, the facilitator first demonstrated how the robot works in a basic sense; she described the robot's pre-programmed actions such as walking, talking, sitting, waving, and had the robot demonstrate those actions. She then showed a video of how the children could program it by 'writing' their own code. The three-minute video demonstrated how to use the Choregraphe library, how to drag and drop the boxes from the library, and how to compile and output the code sequence to make the robot speak and move. The purpose of this stage was to introduce the physical capabilities of the robot and to show how these correspond to simple 'drag and drop' coding sequences.



a. b. c.

Figure 6. 2: a. ‘The humanoid robot cannot run’. b. ‘The robot can walk’. c. Students working with cards to make their own sequence (Stage 2)

Stage 2 (10 minutes): The facilitator then provided the small group of students with fifteen cards that contained different actions that the humanoid robot could and could not do (shown in Figure 3, below). She then showed the children how to sort the cards into a meaningful sequence, which they would need to do before they went on to code with the computer in the next stage. She explained that this activity would not use the computer yet and that its aim was to introduce complex programming concepts in a simple way. The students were asked to identify the actions the robot could do and to use the cards to create their own sequence of actions, as shown in Figure 2, above. The purpose of this stage was to introduce the foundational concept of sequencing in programming by means of a physical, non-digital activity. In recent theories of computational pedagogy, this is known as ‘unplugged’ activity (Kotsopoulos et al., 2017). With unplugged activity, children are able to undertake the process tasks in more traditional ways, which allows them to understand programming in context (Curzon et al., 2014). This experience helps to make challenging computer science concepts simpler to understand. Each group of children worked collaboratively from this stage onwards.

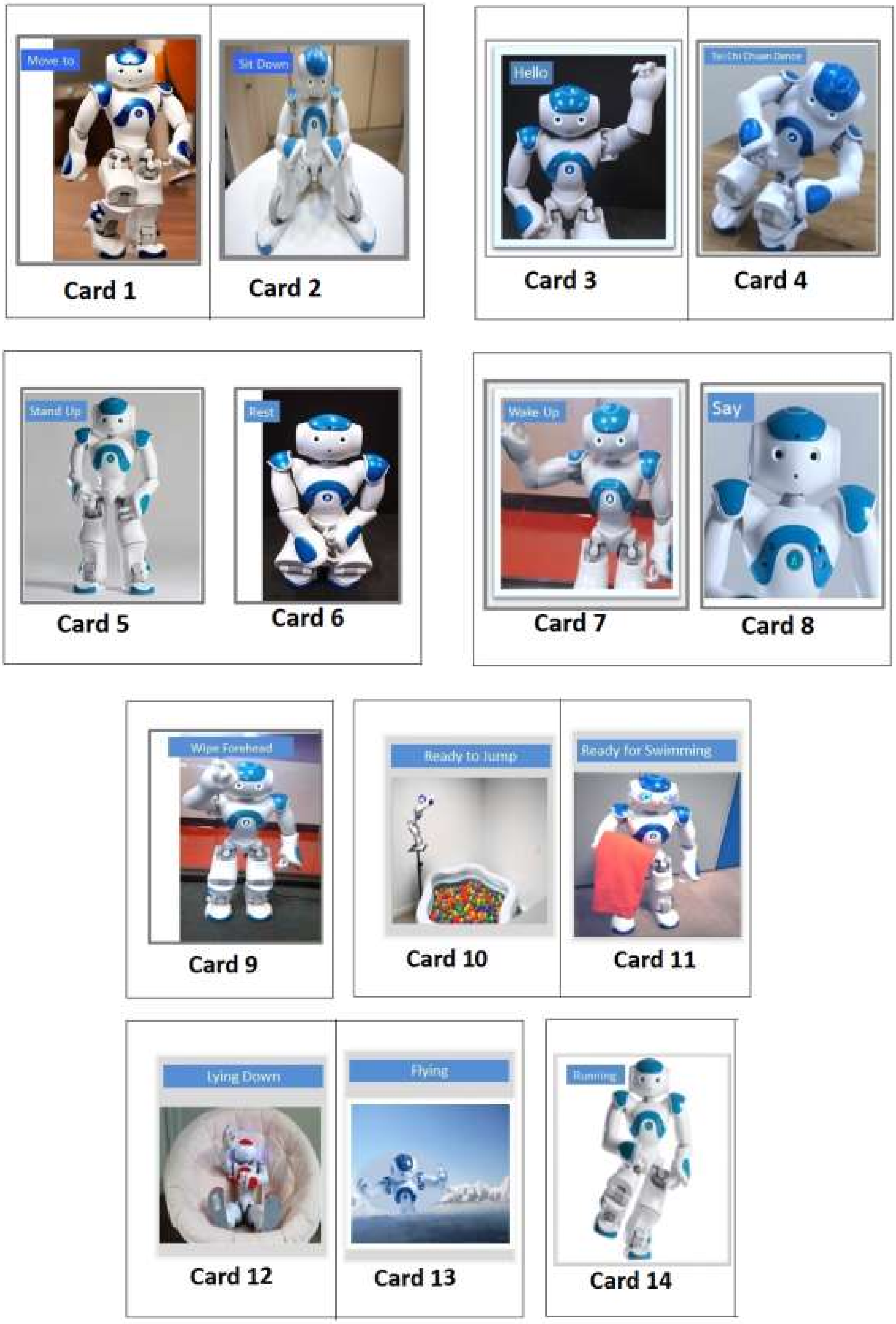
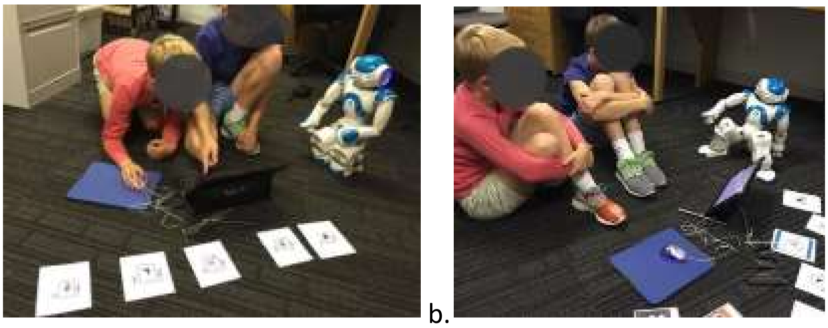


Figure 6.3: All cards used in this learning activity



a. b.

Figure 6. 4: a. Students working with the Choregraphe program. b. the resulting performance by the robot (Stage 3)

Stage 3 (25 minutes): At this stage, the children went on to work using the computer to plan, design, and debug their code collaboratively. This activity was designed so that they could take ownership over the creative process and work collaboratively to solve problems. They explored by themselves how the robot's software works, as shown in Figure 4. They then attempted to use the Choregraphe software's drag and drop functions to make the robot act out the sequence of actions created in Stage 2. The purpose of this stage was for children to develop their potential for digital 'creating' (Kotsopoulos et al., 2017). In recent theories of computational pedagogy, this is also known as 'digital making' (Strawhacker & Bers, 2015).During Stage 4, the children were encouraged to articulate their thoughts and reasons for undertaking various paths and activities. This stage also presented an opportunity to observe children's problem identifying and problem solving behaviour.

Stage 4 (25 minutes): Each group of children was given unstructured 'playtime' with the robot to see if they reused any of the gained knowledge. It was thought that this stage would offer the researcher the opportunity to observe whether the children would apply what they had learnt in different ways and whether they would further explore the capability of the robot.

6.2.2 Learning objectives for the redesigned learning activity

This learning activity design in part drew on and adapted the following set of CT heuristics proposed by Duncan et al. (2014), which grouped children based on the level of 'Initial Learning Environment' (Duncan et al., 2014):

> Level 0: When children's ages range from 2 to 7 years they can start to learn programming using very simple techniques such as drag-and-drop. Teachers can plan to teach them only sequence (Duncan et al., 2014, p. 65).

Level 1: When children's ages range from 5 to 10 years they can learn to drag-and-drop and possibly, to a small degree, tackle abstraction. Teachers can perhaps plan to teach them a few “functions, variables, iteration, indexed data structures, and conditional execution” (Duncan et al., 2014, p. 65).

Level 2: When children's ages range from 8 to 14 years. They can use drag-and-drop or text based coding techniques. Teachers can possibly include some abstraction. Children can learn some or most “functions, variables, iteration, indexed data structures, and conditional execution” (Duncan et al., 2014, p. 65).

6.2.3 Recruitment / procedures for data collection

Participants were invited to contribute to the study through an advertisement in their schools' newsletter (see Appendix). Initially children were invited from two schools; however, the total numbers of schools increased to seven as information spread by word of mouth and children and their parents invited other friends and relatives to participate in the study. Interested parents who gave permission for their children to participate contacted the facilitator via email and telephone.

Thirty-seven primary aged children from Grades 0 to 6 across four private and three public schools in Melbourne were recruited for the study. The students who were interested in the study were likely to have had an interest in robotic technology and possibly programming already. The schools were all located in the eastern and outer eastern suburbs of Melbourne, where the socio-economic status in terms family income tends to be higher, according to ABS census 2006. Schools in these areas may have the opportunity to access better facilities and services than in other parts of Melbourne (ABS Census, 2006). Eleven children were from Preparatory Grade to Grade 2, and 26 children were from Grades 3 to 6. Children attended in 17 groups, a separate session being organised for each of these. Twelve children were female while 25 were male.

Participants' parents received information via email that they and their child could attend a session of one and half hours where the child would undertake a learning activity with a humanoid robot in a group of two or three. Each child had the opportunity to participate in only one session. Confirmation notification included a date and time and the location. The parents and children were also notified that all participation was voluntary and they might cease participation at any time. They were told that they would not be identified in any subsequently published results. For de-identification purposes, each session was coded as

S1,S2, S3….S17 and individual participants were coded by the session number and 'Child Code', for example S1C1, S1C2, S2C3,….S17C37.

Video was used in this study as a method for recording the children's interactions with the robot while they were involved in the learning activity. The benefits of using video are that it can provide comprehensive documentation of technology use as well as capturing non-verbal behaviour of participants (Goldman, Barron & Derry, 2014). Video recordings, when used as a data collection method, contribute to a systematic understanding of the entire activity and richly document participants' behaviour, including their gestures and facial expressions. Video documentation captures both verbal and non-verbal communication, including participants' body language and facial expression, which can be useful in evaluating their experiences and learning processes. This method is also useful for shy children who can be expressive but not verbally articulate (Flannery & Bers, 2015; Goldman, Barron & Derry, 2014))

In addition, video is appropriate for an observational study where children, teachers and/or researchers demonstrate the actions of the robot and its programming actions. Video footage gives context to conversation between the researcher and the participants; it is possible to see exactly what the participants are referring to or working on and how they are using the technology tools. Video provides ways for teachers and researchers to record, timestamp and annotate summaries of children's interactions with the robot, which audio and photographs can only partly do. Video format data supports material-driven activity, and is effective if the analysis of a complex learning process needs to take place a later date (Flannery & Bers, 2015; Goldman, Barron & Derry, 2014).
The video recording protocol meant that the overall observation process needed to encompass three aspects:

1. Videorecording the children's activity and speech, including their facial expression and body language
2. Capturing the content of the laptop screen they were working with
3. Documenting their use of physical materials and resources, for example, cards representing actions for the robot to undertake, the laptop as a physical object and the robot itself

It was not possible for one camera to capture the first two different areas so a video camera for recording the context of use, and screen capturing software (Camtasia) was used for capturing the content of the screen while each group of children were working on their laptop. Procedures for conducting the observational study were as follows:

- The sessions were conducted in a Usability Laboratory at a university in Melbourne, Australia, so the physical and technical context was known to the researcher-facilitator.
- Groups of participants (14 pairs and three groups of three) were scheduled for time slots of approximately one and half hours at times to suit their availability.
- Children arrived to participate in the study in pairs or in groups previously organised by the researcher-facilitator. In some cases groups had been pre-determined by parents of the participants.
- Participants or their parents were invited to complete their demographic questionnaires using hard copies. These initial surveys were undertaken to determine the children's demographics (see Appendix) and their previous use of computers and robots.
- The children were then invited to undertake the activity in their group. A humanoid 'NAO' robot was used in the learning activity; the children used the robot's software to program it to speak and move.
- The activity involved four stages (as described above): demonstration of the robot by the researcher-facilitator, sorting and sequencing activities, working on coding and unstructured playtime. The facilitator was available throughout for support and monitoring.
- Data was recorded using a digital video recorder, screen capturing software and hand written notes. Qualitative data (video recordings, photographs and notes made during the usability testing) and Quantitative data (via the demographic questionnaire) were collected in the study.
- Data was separated from the consent form to enable anonymity and was securely stored by the researcher.
- Video data was later transcribed and analysed using NVivo, which is a qualitative data analysis program for researchers.

6.2.4 Participants

Four main user groups were identified from the demographic survey in terms of firstly, school grade level (lower and upper primary) and secondly, previous experience with programming (non-experienced and some experience). Children who identified as having experience in programming had used one or a combination of Lego Mindstorm, Scratch, Hopscotch, Pascal and Python. These programming platforms are explained below. In total, 19 of the 37 children self-reported having (or were reported by their parent as having) previous experience of programming and 18 had no previous experience. Only two of those participants with experience in programming were in the younger age group (of 11). Fifteen were in the older group (of 26).

Session	Child code	Scratch	Hopscotch	LEGO Mindstorm	Other	Grade level
1	1.01	0	0	0	Python	3-6
2	2.03	1	0	0	0	3-6
2	2.04	1	0	1	0	3-6
3	3.05	0	0	1	0	3-6
3	3.06	0	0	1	0	3-6
4	4.07	0	0	1	0	3-6
4	4.08	0	0	1	0	3-6
5	5.09	0	0	1	0	3-6
5	5.10	0	0	1	0	3-6
7	7.13	1	0	1	0	3-6
7	7.14	1	0	1	Pascal	3-6
8	8.15	1	0	0	0	3-6
8	8.16	1	0	0	0	3-6
9	9.17	1	0	0	0	3-6
10	10.19	0	0	0	Python	3-6
10	10.21	1	1	0	0	Prep-2
11	11.22	0	0	0	Pascal	Prep-2
16	16.34	0	0	1	0	3-6
16	16.35	0	0	1	0	3-6

Table 6.1: Children who were experienced in programming and the platforms they used

Scratch is a screen-based software application for children aged 8 to 16. It can be used by children and adolescents to program their own interactive stories, games, and animations. It aims to encourage them to think creatively and work collaboratively in learning computer skills.

Hopscotch is a visual programming platform where children can create animations and games using drag and drops commands and turn instructions into a lined script. Children can select characters and colourful monsters or animals, which can be customisable.

LEGO Mindstorm is a platform that enables users to construct, program and test their own robots. It needs a visual programming tool to make the constructed robot move.

Python and Pascal are both text based programming platforms. Users need to write code as text, following a specific format, and then they can compile it and run the output.

The user groups were:

- **User Group 1**: Nine lower primary level children (Prep to Grade 2) who were non-experienced in programming ((S1C2, S10C20, S12C24, S14C29, S14C30, S15C31, S15C32, S17C36, and S17C37)
- **User Group 2**: Two lower primary level children (Prep to Grade 2) who had experience in programming (S10C21 and S11C22)
- **User Group 3**: Nine upper primary level children (Grades 3 to 6) who were non-experienced in programming (S6C11, S6C12, S9C18, S11C23, S12C25, S13C26, S13C27, S13C28 and S15C33)
- **User Group 4**: Seventeen upper primary level children (Grades 3 to 6) who had experience in programming (S1C1, S2C3, S2C4, S3C5, S3C6, S4C7, S4C8, S5C9, S5C10, S7C13, S7C14, S8C15, S8C16, S9C17, S10C19, S16C34, S16C35)

This study did not take into account children's gender.

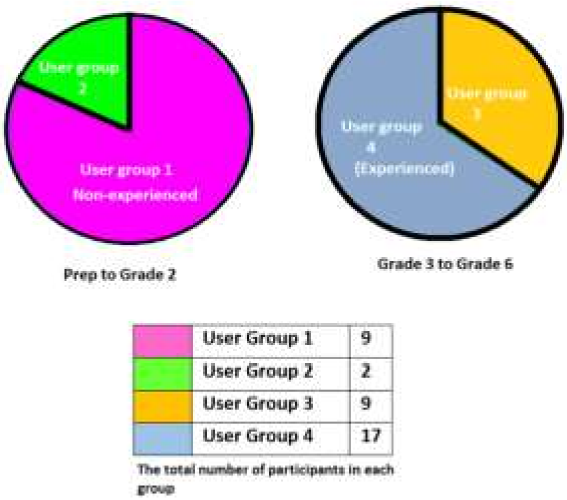


Figure 6.5: Early primary (Prep to Grade 2) and upper primary (Grades 2 to 6) children with and without experience in programming

6.3 Results and discussion

The next five sections use the computational practice 'approaches' proposed by Csizmadia et al. (2015) to categorise and discuss the observed behaviour of the four main user groups during their sessions in which they engaged with the learning activity in pairs or groups of three. The general aim of this was to see whether the robot would be useful to help primary school children learn computational practice.

6.3.1 Approach 1: Creating

In 1980, Papert introduced the notion that learning is analogous to building with concrete materials and tools, which are physically handled and manipulated (Papert, 1980; p.173). His ideas were grounded in the principle of 'making experiences'. In programming, creating includes planning to code, making the programming 'tangible', prototyping and testing the program (Kotsopoulos et al., 2017). In this study, Papert's theme was observed in relation to the children's learning when they made sequenced actions in cards, created storyboards, chose and linked actions on the screen, and made programmed sequences resulting in the robot's movement and speech. 'Creating' therefore occurred through the tangible programming (physical computing) of the robot using its Choregraphe software. The children had the opportunity to learn through sorting, sequencing using cards and visual coding. In the unplugged activity, they worked with the physical cards and sequenced the cards at the beginning to acquaint themselves with core concepts of programming without the use of a computer or the robot (Kotsopoulos et al., 2017). They started by sorting the cards to identify actions that the robot could do by remembering from the demonstration of the robot, and their general knowledge.

After the unplugged experience, they worked on visual programming that was screen based. They then used their sorted cards to make their own storyboard, which was a physical example of sequencing. They made a digital sequence on the screen to make the robot speak and move. They learned how to make interactions between the digital and the real world through their creative use of the robot's software. Digital creating experiences involve making plans, selecting tools, reflecting, problem-solving, communicating, and make connections across concepts. Students have the potential to learn through the construction and through the sharing of what they do (Dougherty 2012).

Observed behaviours related to 'creating' in computational practice

As noted above, more research needs to be undertaken into how children can develop in their computational practice by observing how they engage with programming to create digital and technological artefacts (Brennan & Resnick, 2012). All the children in this study achieved the following 'task goals', also illustrated in Figures 6.6-6.11, below:

- Sorting cards and designing a storyboard in a pair or group of three (Figures 6.6 and 6.7)

- Writing code and creating a sequence on the screen in a pair or group of three (Figures 6.8 and 6.9)
- Creating interactions between the coding on the screen and the robot in a pair or group of three (Figure 6.10)

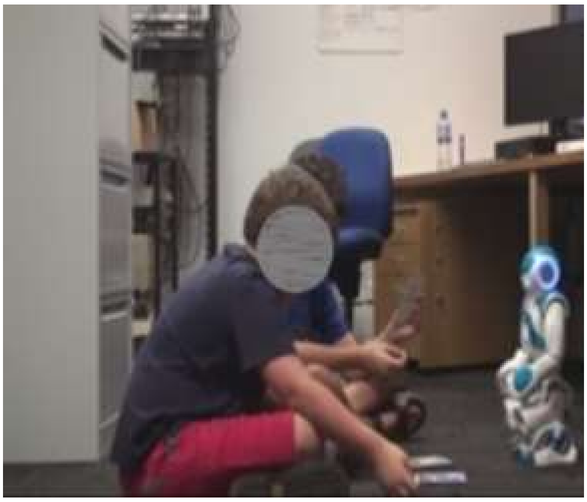


Figure 6.6: Sorting cards (still from the video recording)

Figure 6.7: Creating storyboards (still from the video recording)

Figure 6.6, shows two participants sorting cards after the facilitator explained the activity and gave them a mixed stack of cards. The participants needed to identify what actions the NAO robot could or could not do by making two separate groups of cards. The following section presents dialogue from this part of the video as an example of the way the participants communicated in this activity and conceptualised their first task.

Child 7: [takes one card] *This one it can do* [starts making a pile] Child 8: [takes the next card] *That's what he can't do* [starts making another pile] Child 7: [takes the next card] *That's [pause] he can because I saw it* Child 8: [looks at the card] *Is this the dance we saw?* Child 7: *Yes, so he can do it* [puts the card in a pile and takes another] *He can't lay down* [puts the card in a pile and takes another] *He can't run because it's too fast for the robot*. Child 8: [takes the next card and puts it in a pile] *He can't fly, he can't lay down [pause]* [spreads out and looks at the remaining cards] *So it can't do fly, lay down, jump and swim* Child 7: [gestures at one pile] *This is all the stuff it can do*

Figure 6.8: Creating a sequence (still from the video recording)

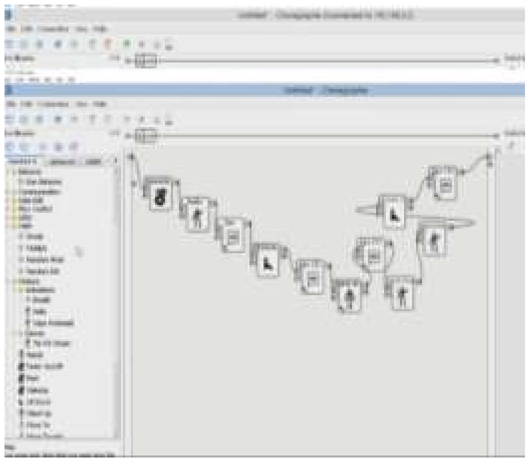


Figure 6.9: Screen capture of a typical code sequence

The following section describes the action and presents dialogue from this part of the video as an example of the way the participants communicated in this stage of the activity. One child (15) has control of the mouse throughout this activity stage.

Child 15: [in silence: looks at the storyboard, looks to find 'Wakeup' in the library, using the mouse drags and drops this action on the screen; repeats the sequence with 'Say']
Child 16: [looks on] *Now, we need to find Tai chi dance*
Child 15: [in silence: finds 'Tai Chi dance', in the library, drags and drops this action on the screen]
Child 16: [looks on] *Then the wipe forehead and then rest*
Child 15: *We need to connect the lines between boxes* [clicks on the 'Say' box and manually types in 'Hi'
Child 16: [looks on] *Add [pause] would you like to see my dance* [points at commands*] now root and then play*
Child 15: [presses the play button] ...

Figure 6.10: Children after a successful coding output—the robot is 'sitting down' from the 'stand up' position (still from the video recording)

The following section describes the action and presents dialogue from this part of the video as an example of the way the participants communicated in this stage of the activity. The participants are resting and looking at the robot after a successful coding output that followed the sequence described in Figure 6.8, above. The robot is 'sitting down' from the 'stand up' position.

Child 15: *I like this robot [indistinct] looks and does things like a human. He's so cool, dancing, speaking.* Child 16: *Just like an upgraded human, dancing, sit down, wake up...*

Other examples of these initial kinds of observed behaviour were:

> Child 23 identified most of the actions that the robot could or could not do, although they were confused by the 'lie down' action on one card. (Session 11, User Group 3)
>
> Child 2 looked at their storyboard made with cards, and remarked that they had programmed half of their sequence on the screen. This child pointed out a similarity between the sequencing activity while storyboarding with cards and the sequencing activity while programming on the screen. (Session 1, User Group 1)
>
> Child 7 wondered aloud about what would be a workable sequence while they created their storyboard. They then changed the sequence of the cards to create a more achievable story. (Session 4, User Group 4)

All the children who participated in this study also showed behaviour signifying a ‘successful moment’ of realisation of output or task completion at least once during their session, for example:

> Child 3 asked the facilitator to endorse their successful code output. [Session 3, User Group 4]
>
> Child 8 was visibly pleased to see their code and the final output. [Session 4, User Group 4]
>
> Child 13 looked excited when the robot started to walk following their code. [Session 7, User Group 4]

However, creating is not only performing programming tasks successfully; in this context it also means that children understand how the components and stages of their activity lead to something new. In this study, children were observed not only undertaking separate tasks accurately (which was coded as ‘low-level creating’) but also understanding the logic behind the successful task completion in order to generate further output. This higher-level ‘creating behaviour’ followed from children identifying a connection between the virtual and the physical robot through coding on the screen. Sometimes their verbal explanation showed they understood this (Strawhacker & Bers, 2015). Therefore the following kinds of ‘understanding while creating behaviour’ were considered indicators of high-level ‘creating’:

- Deliberate and ongoing monitoring of the relationship between the visual coding and the physical robot: this was observed when children looked repeatedly back and forth between the robot and the coding screen green lines that indicated the actions being currently performed by the robot (see Figure 12) to check that the robot’s behaviour was matching the coding sequence
- Articulating an understanding of what tasks were being undertaken and why (Dougherty, 2012): this was demonstrated by the children’s verbal explanation of the relationship between the code on the screen and the physical robot.

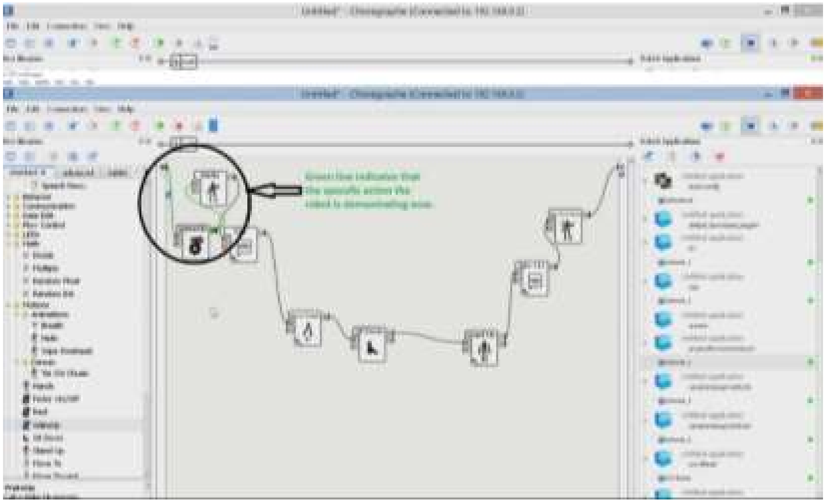


Figure 6.11: Green line indicating the robot's current action (screen capture)

'Creating' in this sense meant seeing these connections and understanding them enough to go on to create an activity for the robot that was new in the context of the learning activity and had not already been demonstrated by the facilitator.

The following examples of observed behaviour show this:

> Child 2 looked at their storyboard and mentioned that they had programmed half of their sequence on the screen. They then remarked on a similarity between the sequencing involved in making the storyboard using cards and the sequencing involved when they programmed the activity on the screen. (Session 1, User Group 1)

> Child 7 made a workable sequence during creation of their storyboard by changing the sequence of their cards to make a more viable story. (Session 4, User Group 4)

> Child 34 often pressed the play button to check the output of their coding and looked at the screen to check the coding while the robot was moving. They pointed out a connection between coding and the responses of the robot. (Session 16, User Group 4)

The following examples show children starting to conjecture (Dougherty, 2012), for example explaining why things were happening:

> While creating their own sequence, Child 13 started wondering aloud about which actions the robot needed to perform before doing the next actions to create a viable sequence based on the storyboard. This child explained that the robot would need to stand up first before doing the dance, and so they needed to use the 'wake up' action at the beginning as the robot was in 'resting' mode. (Session 7, User Group 4)

After Child 5 changed the values of various parameters, the robot started to walk faster sideways, forwards and backwards. They identified how to control these parameters and explained which values of x and y caused the robot to move forward, backward and into other positions. (Session 2, User Group 4)

The breakdowns between the ‘checking back and forth’ and the ‘speaking about the digital/physical relationship’ behaviours are shown in the tables below and in Figure 13 where each line represents a child and gives that child's code number in the study, and the colours represent the different user groups. As the numbers in each user group were not equal, the total numbers of children in each user group are given in the colour key panel.

Children checking back and forth between the robot and the screen

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	1	7
Non-experienced	1	2

Children speaking about the relationship between the robot and the screen

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	0	11
Non-experienced	0	3

Child checking back and forth between the robot and the screen as they made something
1
3
9
11
14
15
16
22
23
29
34

Child speaking about the relationship between the robot and the screen as they made something
3
4
5
6
7
10
11
13
16
17
18
23
34
35

	User Group 1	9
	User Group 2	2
	User Group 3	9
	User Group 4	17

The total number of participants in each group

Figure 6.12: high-level ‘creating’ behaviour

As shown in Figure 13, not all children demonstrated these kinds of higher-level creating behaviour and they were mainly found among children who were both older and had some prior experience in programming with other platforms.

When taken all together, the numbers of children who made this connection between the coding and the robot showing that they understood how it affected what they could do (either in terms of the ‘checking back and forth’ body language or speech) were:

- One out of nine **User Group 1** participants showed understanding in creating their work (Grades Prep to 2 with no prior experience in programming). (S14C29)
- One out of two **User Group 2** participants showed understanding in creating their work (Grades Prep to 2 with some experience in programming). (S11C22)
- Three out of nine **User Group 3** participants showed understanding in creating their work (Grades 3 to 6 with no prior experience in programming). (S11C23, S9C18, S11C23)
- Fourteen out of seventeen **User Group 4** participants showed understanding in creating their work (Grades 3 to 6 with some experience in programming). (S16C35, S16C34, S1C1, S3C5, S2C4, S7C14, S8C15, S9C17, S5C9, S5C10, S4C7, S2C3, S8C16, S7C13)

Low-level 'creating behaviour' was observed in Stages 2 and 3 of the learning activity. The purpose of Stage 2 was to introduce planning and sequencing as 'unplugged' foundational concepts of programming without the use of technological devices. The observations showed that all participants were able to 'identify actions that the robot could do' and 'create a sequence successfully' by making appropriate storyboards using physical cards. The purpose of Stage 3 was to apply this sequencing skill in a computational context. All participants were able to 'create a sequence successfully' using the Choregraphe computer software.

Higher-level creating behaviour was observed in Stages 3 and 4 of the learning activity, mainly among the older children and particularly among those with some experience in programming. All participants were able to acquire and/or make use of foundational sequencing skills by applying them in digital making, even those who had not programmed before. However, it seemed that not all of them could explain what they had made or show nonverbally that they were making connections between their visual coding and the physical robot. Only one out of the nine User Group 1 participants and one out of two of the User Group 2 participants demonstrated this higher-level kind of creating. Among the older children, only three out of nine User Group 3 participants demonstrated this, as opposed to 14 out of 17 more experienced User Group 4 participants.

The children's behaviour with respect to emotional excitement and active participation during programming were also coded in this study and it was clear that the children were all highly engaged during their sessions with the robot. According to Reschly & Christenson (2012) "Engagement is viewed as multidimensional, involving aspects of students' emotion, behaviour ... and cognition" (p.3). The observations showed that the children were visibly interested in working with the robot, in sorting the cards and reflecting on its capability, in creating their own storyboards based on its predicted capability and in working on programming using a laptop to make the robot speak and move. These results concurred with the teachers' expectations described in Chapter 4, although they would need to be tested in a real classroom setting. However, it was also noted that some children were distracted by the engagingly humanoid and toy-like aspects of the robot, as had also been predicted by the teachers.

6.3.2 Approach 2: Debugging

During digital making, unexpected errors can arise. In this context "making encourages students to combine multiple ideas into a cohesive process, organize their understanding in new ways, and 'debug' understandings in their instructions to produce something unexpected " (Kotsopoulos et al., 2017, p.163). Because of the complexity of programming, learners often have issues with their coding and they need to learn how to identify these and fix them. This is an important part of learning to think and to work like a programmer in learning from mistakes (Chen et al. 2017; Brennan & Resnick, 2012). The process of debugging others' code can also a way of gaining practice in collaborative behaviour.

Observed behaviours related to 'debugging' in computational practice

'Debugging approaches' were demonstrated by participants on various occasions when they had difficulty during coding. This was mainly when the expected output did not occur; children would then start thinking through the code, and working to identify and fix the error/s. Debugging was observed in Stages 3 and 4 of the learning activity and was characterised by the following behaviours:

- Identifying programming problems independently (as shown in Figure 15)
- Solving issues by asking the facilitator for information (as shown in Figure 16)
- Solving issues independently or with their groupmates

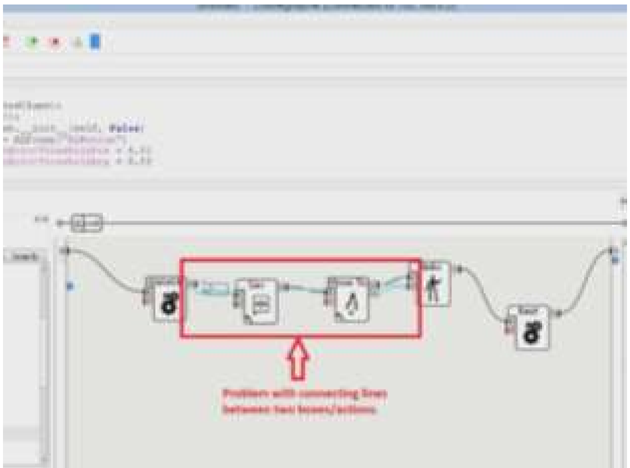


Figure 6.13: A coding error that needed to be debugged (screen capture)

Figure 6.14: The facilitator made suggestions about solving coding problems

Identifying problems independently

The first component of debugging behaviour was observed when children were able to identify programming issues by themselves (without the help of the facilitator). Examples were:

> Child 19 noticed the robot did not dance when they checked the output of their program. They returned to the programming screen and started to check the sequence of the screen. This child identified the problem and discussed it with the other child,

asking why the robot did not dance. They then identified a connection problem between two actions. (Session 10, User Group 4)

Child 9 found a problem of logical flow in their code; they had used 'stand up' then 'wake up', which was not a meaningful sequence. (Session 5, User Group 4)

The numbers of children who demonstrated this kind of debugging approach were as follows:

- One out of nine **User Group 1** participants independently identified one or more programming problems (Grades Prep to 2 with no prior experience in programming). This child worked in a group of three children where the other two were both Category 3 participants (older and experienced in programming). (S10C20)
- One out of two **User Group 2** participants independently identified one or more programming problems. (S10C21, S11C22)
- Five out of nine **User Group 3** participants independently identified one or more programming problems (Grades 3 to 6 with no prior experience in programming). (S13C28, S9C18, S11C23, S13C26, S13C27)
- Eight out of seventeen **User Group 4** participants independently identified one or more programming problems (Grades 3 to 6 with some experience in programming) (S10C19, S2C4, S8C16, S9C17, S5C10, S5C9, S8C15, S2C3)

Solving issues with the support of the facilitator

The second component of debugging behaviour was observed when children sought help from the facilitator either verbally or by using body language to attract their attention, in order to enlist their help in solving one or more problems. Examples were:

Child 11 had trouble connecting the lines between boxes in the coding screen (Figure 6.13 and 6.14) because they drew more than one line between the two boxes. They also had problems with the input/output connections. This child appealed to the facilitator, who helped them to solve the problem by replaying the Stage 1 video (Session 6, User Group 3)

Child 1 asked the facilitator why the robot only performed half of their coding and stopped. They checked their coding but could not identify the problem. (Session 1, User Group 4)

The numbers of children who demonstrated this kind of debugging approach were as follows:

- One out of nine **User Group 1** participants solved one or more issues with the support of the facilitator (Grades Prep to 2 with no prior experience in programming). (S17C37)
- One out of two **User Group 2** participants solved one or more issues with the support of the facilitator. (S10C21**)**
- Three out of nine **User Group 3** participants solved one or more issues with the support of the facilitator (Grades 3 to 6 with no prior experience in programming). (S6C12, S6C11, S11C23)
- Ten out of seventeen **User Group 4** participants solved one or more issues with the support of the facilitator (Grades 3 to 6 with some experience in programming) (S1C01, S3C06, S5C09, S4C08, S2C03, S3C05, S5C10, S8C15, S4C07, S8C16)

Solving issues independently

This final component of debugging behaviour was observed when children were able to fix their problem independently or by discussing it with their groupmates, for example:

> When the robot spoke very fast Child 17 changed the value of a parameter for the 'say' command and the robot spoke normally. They then tried to use punctuation key strokes when typing in the text box. Child 24 fixed this issue and checked the output. (Session 9, User Group 4)

> Child 9 found an error in their coding related to the commands 'sit down' and 'walk'. They worked on the screen to fix the sequence. (Session 5, User Group 4)

Only children who had experience in coding (in **User Groups 2 and 4)** showed this behaviour. One out of two **User Group 2** participants and ten out of 17 **User Group 4** participants showed this behaviour by independently solving one or more issues. (UG2: S10C21; UG4: S1C01, S2C04, S2C03, S9C17, S3C06, S3C05, S4C08, S5C10, S5C09, S4C07)

Identifying problems independently

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	2	8
Non-experienced	1	5

Solving issues with the support of the facilitator

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	1	10
Non-experienced	1	3

Solving issues independently

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	1	10
Non-experienced	0	0

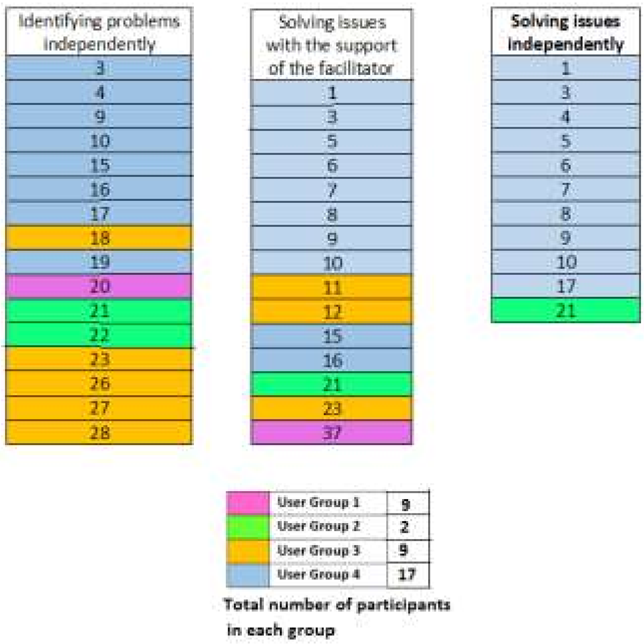


Figure 6.15: Evaluation of debugging in terms of the three components

The observations showed that the debugging approach was only demonstrated to its fullest extent (*both* identifying *and* solving issues) by seven older participants who also had some prior experience in programming (i.e., in User Group 4) (C3, C4, C9, C10, C15, C16, C17). Of these seven, five solved one or more of these problems *independently* (C3, C4, C9, C10, C17), the others only with the help of the facilitator. Twelve (out of seventeen) children in this group (User Group 4) debugged code that they or another child had identified as having an issue (but of these twelve, five had not themselves identified an issue that needed fixing) and one identified an issue without debugging it.

However, none of the User Group 1 participants both identified and solved an issue and only one User Group 2 participant did so. Although five out of nine User Group 3 participants with no prior programming experience identified issues, only three out of nine solved one or more issues with the help of the facilitator and as mentioned, of these, only one both identified and solved an issue. One out of nine of the younger and inexperienced participants identified an issue and one different child from this user group solved an issue (which had been identified by another child) with the help of the facilitator.

6.3.3 Approach 3: Collaboration

Educators have noted that meaningful collaboration is a key skill for participation in both educational and workforce environments (Worrell, Brand & Repenning, 2015). In general, collaboration happens when people work together to confirm the best outcome. Collaborative group-work is already prominent in primary schools and collaboration happens in all subjects. By collaborating in their computational practice, children can share their knowledge and skills by demonstrating behaviour and by explaining their thoughts to each other in order to develop their ‘logical thinking skills’ (Csizmadia et al., 2015).

Collaboration in programming happens when children can share a screen and a keyboard for writing codes by sharing their ideas, swapping their roles, conferring together to solve a problem, and creating something effective based on their learning. According to Worrell, Brand & Repenning (2015), two to four children can work in a group to build a computational sequence and teachers can assign a specific task to a member of a group. Csizmadia et al. (2015), however, proposed that the most effective way to learn programming is working in pairs, as two programmers can share a programming screen or device, with a mouse and a keyboard, working together to create their coding. Normally one programmer can work on coding by using the keyboard, and the other can take the role of a navigator by observing the high-level view on the screen. They can also swap these roles.

Collaboration skills have been measured in other research in terms of how children discuss their thoughts with each another, how they listen to others, whether they help each other, whether their role is that of a 'driver' or a leader or a navigator, and whether they swap roles (Csizmadia et al., 2015).

In this study, children worked in pairs or groups of three, but a specific role or task was not assigned to each group member by the researcher, who was keen to observe how roles would be assigned on a group basis in a flexible environment where the children could suit their own interests and abilities.

Observed behaviours related to 'collaborating' in computational practice

Collaborative behaviour was identified in this study while children worked in pairs or groups of three on their tasks and free play. Several indicators of collaboration were used:

- group leadership: taking initiative in group-oriented behaviour with the aim of engaging in an activity or solving a problem
- 'joining in' with group work after encouragement from the group
- conferring in a group-related activity
- swapping control of the keyboard in the course of engaging in an activity or solving a problem.

Group leadership

This approach was observed in the video data when children took the initiative in group-oriented behaviour when beginning a new task or solving an issue without being prompted by the facilitator. For example,

> When the facilitator asked a group of children to begin a first new task by identifying the actions that the robot could or could not do using cards, Child 2 took the initiative by receiving the cards from facilitator, and explaining to the other members how they could proceed with this task as a group. (Session 1, User Group 1)
>
> When the facilitator prompted the group to select cards to make a storyboard, Child 28 took the initiative by selecting cards and asking the other to select theirs. This child provided a commentary following the sequence of the story. (Session 13, User Group 3)

The numbers of children showing leadership in group-work were:

- Seven out of nine **User Group 1** participants showed leadership (Grades Prep to 2 with no prior experience in programming). (S1C2, S17C36, S14C30, S15C32, S12C24, S14C29,and S15C31)
- One out of two **User Group 2** participants showed leadership (Grades Prep to 2 with some prior experience in programming) (S11C22)
- Nine out of nine **User Group 3** participants showed leadership (Grades 3 to 6 with no prior experience in programming) (S13C27, S15C33, S13C28, S12C25, S13C26, S6C12, S11C23 and S6C11)
- Fifteen out of seventeen **User Group 4** participants showed leadership (Grades 3 to 6 with some experience in programming) (S2C3, S5C9, S16C35, S3C5, S5C10, S7C13, S4C7, S8C15, S9C17, S2C4, S10C19, S1C1, S8C16, S16C34, S7C14)
- Five children out of thirty-seven did not show leadership. (S3C6, S4C8, S10C20, S9C18, S17C37)

Acting following encouragement in group-oriented behaviour

This behaviour was observed in the video data when children acted with the encouragement of the other group member/s. It included children joining in in identifying actions that the robot could or could not do, creating storyboards, finding actions in the library, helping to solve issues during programming and generating output. For example,

> Child 2 started to do some programming when the other child encouraged them. (Session 1, User Group 1)
>
> Child 8 followed Child 9's encouragement to look on and imitate their actions using the cards. Child 8 then encouraged another child to select cards and create a storyboard. (Session 4, User Group 4)

The numbers of children who joined in with group work following encouragement were:

- Seven out of nine **User Group 1** participants joined in with the others (Grades Prep to 2 with no prior experience in programming) (S17C37, S1C2, S12C24, S14C29, S14C30, S15C31, S15C32)
- One out of two **User Group 2** participants joined in with the others (Grades Prep to 2 with some prior experience in programming) (S11C22)
- Six out of nine **User Group 3** participants joined in with the others (Grades 3 to 6 with no prior experience in programming) (S12C25, S13C26, S9C18, S15C33, S6C12, S11C23)

- Eight out of seventeen **User Group 4** participants joined in with the others (Grades 3 to 6 with some experience in programming) (S1C1, S8C16, S16C34, S16C35, S7C14, S2C4, S4C8, and S9C17)
- Fourteen children out of thirty-seven did not show this behaviour. Instead they took a leadership position or helped each other; for example, Child 11 took initiative by asking their partner to take the mouse to solve their problem related to finding actions in the library. (S10C20, S10C19, S5C9, S3C5, S5C1, S3C6, S13C27, S13C28, S2C3, S17C36, S6C11, S7C13, S4C7, S8C15)

Helping each other

Collaboration was also shown when children helped each other, solving their problems, asking them for help, agreeing to help and undertaking tasks together by social negotiation.

Some examples of this were:

> Child 29 helped another child to find actions in the library while they generated their sequence on the Choregraphe screen. The child also helped by providing the ideas for the 'say' action. (Session 14, User Group 1)
>
> Child 3 took a card after asking Child 4 for permission. Child 4 then asked Child 3 for their opinion. (Session 2, User Group 4)
>
> Child 3 discussed with child 4 the 'say' action and encouraged him to type in something. After creating their sequence on the screen, Child 3 asked Child 4 their opinion about checking the sequence before pressing the output button. (Session 2, User Group 4)
>
> Child 13 helped Child 14 to delete some actions from the previous sequence to create a more viable story. (Session 7, User Group 4)

The numbers of children who worked collaboratively by helping others in their group were:

- Six out of nine **User Group 1** participants helped others or another (Grades Prep to 2 with no prior experience in programming) (S17C36,S17C37, S14C30, S14C29, S15C31,S1C2)
- One out of two **User Group 2** participants helped others or another (Grades Prep to 2 with some prior experience in programming) **(**S10C21)
- Six out of nine **User Group 3** participants helped others (Grades 3 to 6 with no prior experience in programming) (S9C18, S12C25, S15C33, S6C12, S11C23, S6C11)

- Fourteen out of seventeen **User Group 4** participants helped others (Grades 3 to 6 with some experience in programming) (S3C5, S3C6, S5C9, S16C35, S7C14, S9C17. S1C1, S8C15, S2C4, S8C16, S5C10, S2C3, S7C13, S4C7)
- Nine children out of thirty-seven did not show this behaviour (S10C19, S10C20, S4C8, S13C27, S13C28, S13C26, S16C34, S15C32, S12C24)

Swapping control

Control swapping was recorded in order to investigate children's attitudes to switching roles.

Voluntary control swapping

This behaviour was shown when children changed their roles or tasks by negotiation, asking each other and accepting the other's opinion.

> Child 24 asked permission to take the mouse to delete lines on the screen. (Session 17) (Prep to grade 2 and non-experienced)
>
> Child 6 asked his mate to switch roles. (Session 3) (Grade 3 to 6 and experienced)
>
> Child 12 asked whether they could take the mouse to work out why the robot did not dance. (Session 6) (Grade 3 to 6 and non- experienced)

The numbers of children who swapped roles by negotiation were:

- Seven out of nine **User Group 1** participants swapped control voluntarily (Grades Prep to 2 with no prior experience in programming) (S10C20, S14C29, S15C32, S17C36, S14C30, S12C24, S15C31)
- One out of two **User Group 2** participants swapped control voluntarily (Grades Prep to 2 with some prior experience in programming) (S12C22)
- Eight out of nine **User Group 3** participants swapped control voluntarily (Grades 3 to 6 with no prior experience in programming) (S13C28, S12C25, S15C33, S6C12, S11C23, S6C11, S13C27,and S9C18)
- Fourteen out of seventeen **User Group 4** participants swapped control voluntarily (Grades 3 to 6 with some experience in programming) (S3C5, S8C16, S3C6, S5C10, S2C3, S4C7, S9C17, S5C9, S16C35, S7C14, S8C15, S16C34, S2C4, and S7C13)
- Six children out of thirty-seven did not show this behaviour (S1C1, S1C2, S4C8, S10C19, S13C26, and S17C37)

Involuntary control swapping

This behaviour was shown when children swapped their roles without asking or receiving permission from the other children in their group.

The numbers of children who swapped roles without asking permission were:

- Zero out of nine **User Group 1** participants swapped control without asking permission (Grades Prep to 2 with no prior experience in programming)
- Zero out of two **User Group 2** participants swapped control without asking permission (Grades Prep to 2 with some prior experience in programming)
- Three out of nine **User Group 3** participants swapped control without asking permission (Grades 3 to 6 with no prior experience in programming) (S11C23,S6C11,S9C18)
- Ten out of seventeen **User Group 4** participants swapped control without asking permission (Grades 3 to 6 with some experience in programming) (S4C8, S3C5, S5C10, S9C17, S7C14, S8C16, S8C15, S7C13, S5C9, S2C3)
- Twenty two children out of thirty-seven did not show this behaviour (S1C1, S1C2, S13C26, S17C37, S13C28, S12C25, S15C33, S14C29, S15C32, S17C36, S14C30, S13C27, S12C24, S16C35, S15C31, S16C34, S10C19, S10C20, S6C12, S3C6, S4C7, and S2C4)

Group leadership

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	1	15
Non-experienced	7	8

Join in a group

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	1	8
Non-experienced	7	6

Swapping control (voluntary)

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	1	14
Non-experienced	7	8

Swapping control (involuntary)

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	0	10
Non-experienced	0	3

Helping each other

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	1	14
Non-experienced	6	6

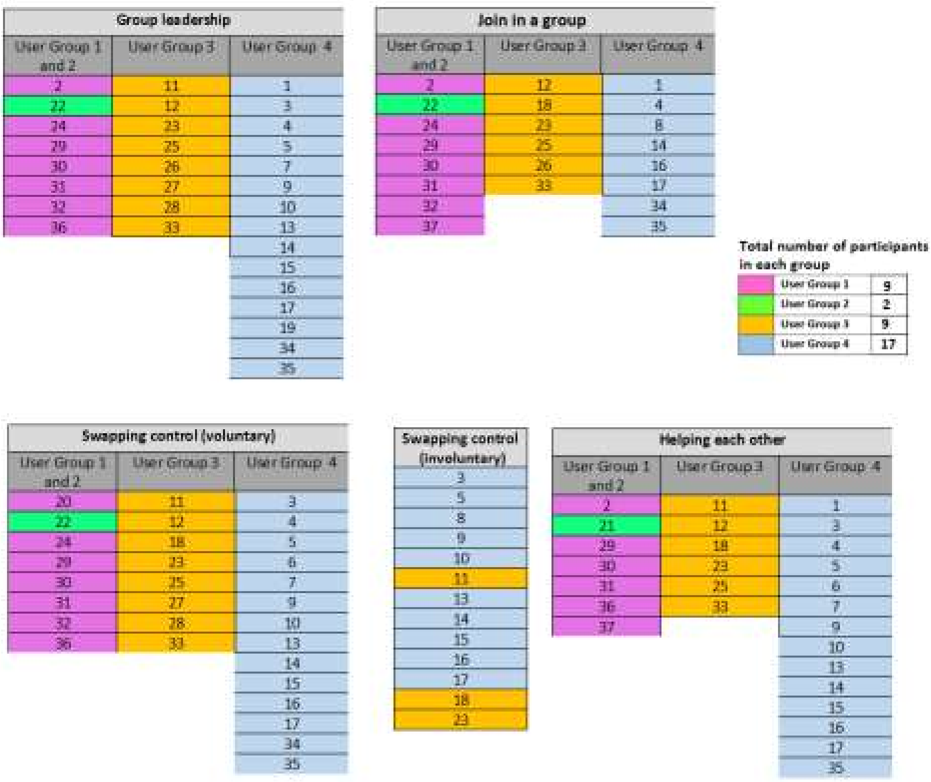


Figure 6.16: Types of collaborative behaviour

As shown in Figure 18, most children in this study readily collaborated in some way/s and it seems that this aspect of the study would need to be differently designed to deliver richer and more granular information about the robot's capacity to enhance children's collaboration skills as part of their computational practice. However, a separate observation of the groups' internal dynamics did endorse Csizmadia et al.'s (2017) comments about optimal group size, noted above, in that in this admittedly small-scale study, the pairs worked together much more productively than did the groups of three.

6.3.4 Approach 4: Tinkering

In computational practice, 'tinkering' is playful experimentation in creating or modifying a computer program; tinkering is exploratory and unplanned (Berland, Martin, Benton, Petrick Smith, & Davis, 2013). Berland et al. (2013) note that tinkering includes "trial and error, messing around or fussing, finding and using feedback mechanisms (such as testing), or combinations of those activities” (p. 568). Others researchers have suggested that tinkering is not a useful activity for beginners in programming and Yeshno & Ben-Ari (2001) describe it as 'aimless' (cited in Berland et al., 2013, p. 569). However, tinkering has more recently been recognised as an important aspect of computational learning (Kotsopoulos et al., 2017; Berland et al., 2013).

Observed behaviours related to ‘tinkering’ in computational practice

Tinkering behaviour was observed in some of the children when they had free 'playtime' at the end of their learning activity session. The facilitator deliberately did not give them any set tasks or suggestions for coding or using the robot during this time. Children who tinkered often found a different function of the robot than they had used during the more directed tasks, which they then explored during the unstructured playtime. Sometimes they identified new actions in the library and found how these worked (perhaps using them to create a sequence), or they tried to make two or more actions work at the same time.

For example,

> Child 34 identified the ability of this robot to speak different languages through the Choregraphe software. The child changed the language to Arabic and typed in phrases in Arabic using English letters. (Session 16, User Group 4)
>
> Child 34 also identified the ‘waiting time’ action, which was not demonstrated by the facilitator. This child also worked out how two actions could be performed by the

robot at the same time—both saying 'hallo' and waving a hand. (Session 16, User Group 4)

Child 18 identified and explored action parameters. They changed the values of parameters to see the robot's responses according to the changes. This child worked out how to make the voice of the robot slower or faster using the 'say' action parameter. (Session 9, User Group 3)

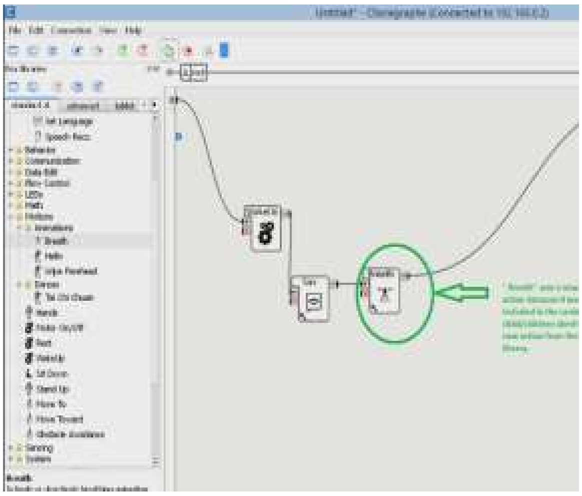


Figure 6.17: The child identified actions that were not included in the cards

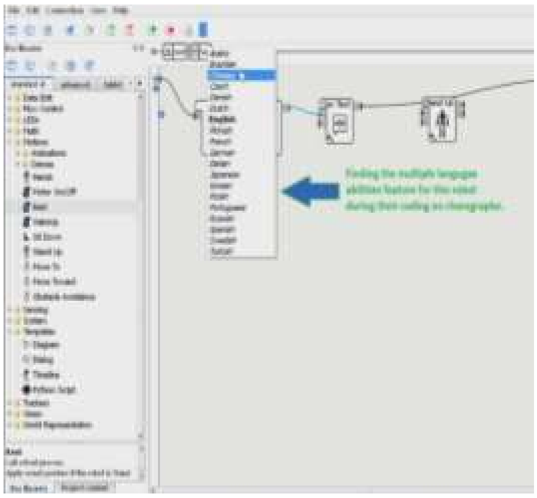


Figure 6.18: The children explored the multiple language selections within the software

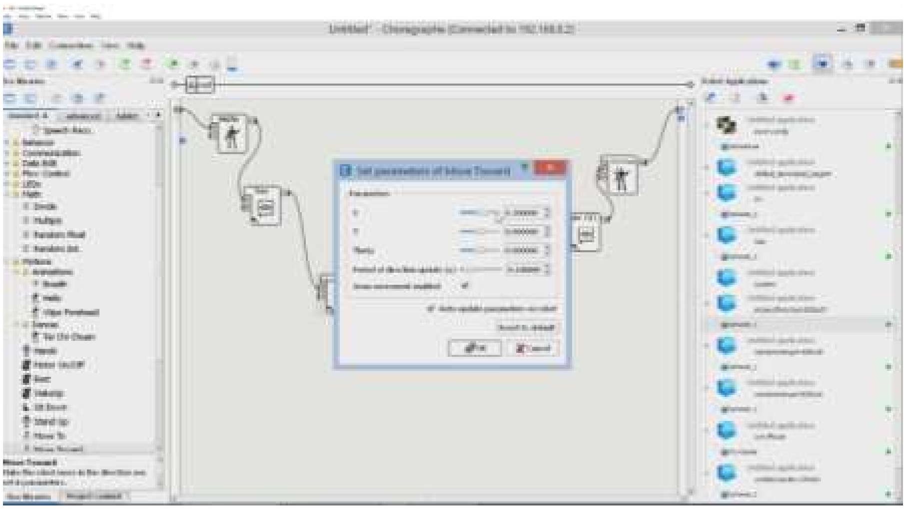


Figure 6.19: The child worked out how to use variable parameters

The numbers of children who tinkered were as follows:

- Zero out of nine **User Group 1** participants engaged in playful experimentation with their coding (Grades Prep to 2 with no prior experience in programming)
- One out of two **User Group 2** participants engaged in playful experimentation with their coding (Grades Prep to 2 with some prior experience in programming) (S11C22)

- Four out of nine **User Group 3** participants engaged in playful experimentation with their coding (Grades 3 to 6 with no prior experience in programming) (S6C12, S13C27, S6C11, S9C18)
- Nine out of seventeen **User Group 4** participants engaged in playful experimentation with their coding (Grades 3 to 6 with some experience in programming) (S7C13, S8C15, S4C8, S16C34, S4C7, S2C3, S2C4, S9C17, S16C)

Tinkering
3
4
7
8
11
12
13
15
17
18
22
27
34
35

Total number of participants in each group

	User Group 1	9
	User Group 2	2
	User Group 3	9
	User Group 4	17

	Young children (prep to grade 2)	Older children (Grade 3 to 6)
Experienced	1	9
Non-experienced	0	4

Figure 6.20: Tinkering behaviour

In this study, only one of the younger children demonstrated the tinkering approach, whereas the older children (both experienced and non-experienced) were more likely to tinker.

6.3.5 Approach 5: Persevering

Persevering is demonstrated when children have difficulties creating or fixing errors and they keep going despite a complex situation, rather than giving up. Children did not have the opportunity to demonstrate perseverance in this study because of the simple and rather short nature of the learning activity. Persevering as a computational approach would be more easily investigated in the context of a study that took into account students' learning trajectory, which is a topic that is discussed further in the following section.

6.4 Discussion and conclusion

Using a learning activity in a controlled setting allowed the current study to demonstrate how an educational technology intervention design team could perform a preliminary focused needs assessment and capture necessary information about ‘real children’s’ learning trajectories while planning for a localised intervention. The observations described above show that there are affordances of the humanoid robot that would lend themselves to various kinds of learning among the children in the study. In addition, the observations endorse Flannery & Bers (2015) assertion that robotics curriculum needs to be ‘differentiated’ for children of different age ranges.

The study showed that the robot could be used to introduce computational sequencing to lower primary children provided the lessons were well scaffolded using ‘unplugged’ activities (such as the storyboarding activity used here), and also provided that experience-appropriate ‘lower-level creating’ goals were kept in mind. The observations showed that all the younger children were able to gain something in terms of ‘lower-level creating’ from their experience. However, hardly any of the younger children seemed able to make the kinds of connections that would enable them to engage in ‘higher-level creating’ and, although this could reflect various limitations of the controlled study, this gulf merits further investigation. In summarising research undertaken by ‘Tangible K’ project teams, Flannery & Bers focused on the influence of robotics learning on “children’s learning trajectories in computational thinking”, arguing that “cognitive development seems to play a mediating role” (2015, pp. 204 & 218). Although this study focused on the potential influence of the robot on children’s *computational practice* rather than *computational thinking*, it seems possible that children’s cognitive development could play a role in the kinds of ‘digital making’ practice being investigated here. However, given this potential thinking/practice crossover, it also seems possible that computational ‘making’ or ‘creating’ is as yet too under-defined to provide a useful category in ‘approach-’ or ‘practice-’ based computational literacy frameworks.

The study also shows that further thought would need to be given to how tinkering skills could be encouraged among younger cohorts while using this particular robot, and a need for more investigation of this problem is also indicated. Keyboard skills were an issue among the younger children, so touchscreens needed to be used for the drag and drop coding. Despite the issues related to the robot's ability to engage in meaningful conversation, described in Chapter 5, the robot does lend itself fairly readily to being programmed with simple sentences or monologues. However in order to tinker with the speech capability of the robot, the children needed to use a keyboard and to spell words correctly, so no tinkering of this kind was done by the younger children.

In addition, tinkering in robotics usually emphasises the more tactile and kinaesthetic aspects of the engineering process, along with the kinds of code-related tinkering observed here that relate more specifically to computational practice. However, tinkering with the physical components of this robot is not possible, as this would breach the manufacturer's warranty, so the younger students' ability to tinker with it was somewhat constrained. It seems likely that a genuinely robotics-oriented computational practice curriculum would need to be bolstered with other (perhaps lower-tech) options, in order to develop more physical or mechanical tinkering approaches.

Among the children observed in this study, the ability to detect and solve code-related issues was experience-related, which would appear to indicate that the practice of debugging could be learnt by younger children provided it was well-scaffolded as part of a larger syllabus or 'curricular activity system' (Roschelle et al., 2010). The group-work context complicated the evaluation of the children's debugging practice in that in some groups, one child would take on the role of 'debugger in chief'. While this could be regarded as an effective collaborative strategy, it did deny less experienced children the chance to practice 'tracing' code in preparation for debugging (Sentence & Csizmadia, 2017). The extent to which debugging should be learnt on an individual basis has been discussed by Brennan & Resnick (2012), who recommend that teachers give students 'bug-ey' code for individual practice and summative assessment tasks.

Turning now to the older children in the study, as noted above, the observations showed 'higher-level creating' approaches, particularly among the children who had some experience of programming. However there was also a higher proportion of children who were inexperienced in programming but who still showed patterns of realisation regarding the relationship between the code on the screen and the actions and speech of the robot. This would lend weight to Flannery and Bers's (2015) posited relationship between more advanced cognitive skills and age-related outcomes, mentioned above. It would also appear to indicate that these inexperienced children in the older cohort would not need a great deal of scaffolding to 'get up to speed' in terms of their digital making practice; however, this process would clearly need to be factored into the curriculum. In this study, the older children also seemed more inclined to tinker and to debug, which suggests that they should be given plenty of scope to further develop these aspects of their computational practice.

Recently researchers have also proposed so-called 'remixing' as a component of computational practice (Kotsopoulos et al., 2017; Brennan & Resnick, 2012). Remixing is defined as "the appropriation of objects or components of objects for use in other objects or for other purposes" (Kotsopoulos et al., 2017, p.165). As with tinkering, this humanoid education service robot does not lend itself to remixing in a materially engineering sense; however, if it achieved wide use, shareable and 'hackable' digital applications would be expected to emerge among student user communities and education networks (Matuk et al., 2016). One factor that might mitigate against this development, however, is the high cost of this robot.

Many aspects of this discussion have touched on the need to envision these elements of computational practice in terms of a longer learning trajectory. As Roschelle et al. (2010) note, new technology both aligns with and challenges curriculum, and the discussion above gives examples of how using the humanoid robot to teach computational practice would nudge the curriculum in various directions. In particular, the examples presented show that what Roschelle et al. (2010) call 'curricular activity systems' would need to be developed as part of the next design iteration to address the developmental needs of children of different grade and experience levels in their local context.

As the work of the Tangible K project has shown, teachers would also need to be involved in this process (Flannery & Bers, 2015). Roschelle et al. (2010) commented that "teachers are increasingly attuned to the accountability demands of their environment … [and] new technologies must address the core curriculum or face certain marginalization" (p. 239). This mandate was clearly demonstrated in Chapter 4 of this study by the unexpectedly strong emphasis placed by the teachers on the necessity to align the use of the robot with current curricular standards. However, as Roschelle et al. (2010) also argue, new technology demands new curriculum, and any extended use of the robot for the purpose of developing computational literacy would necessitate the creation of new curriculum as part of "a plan for bridging the gap between new technological affordances and what most teachers need and can use" (p.233).

Although this study is limited in scale, it shows that the implementation design would need to take learning trajectory into account and it demonstrates how small-scale but powerful pedagogies encapsulated in a prototype learning activity can provide suggestions as to the likely shape of curricular activity systems that would be needed to target specific cohorts and optimise their learning outcomes. As Flannery and Bers (2015) note, “there is at present still much knowledge left to build regarding how working with new technologies might promote computational thinking in young children and what kinds of learning trajectories lead to the best outcomes” (pp. 203-4). This chapter firstly argued that focusing more specifically on computational practice would provide a more promising basis for this investigation. It also showed how “taking a detour out of the complex classroom environment to conduct a focused study in a simplified … laboratory environment” (p. 199) provided the implementation research team with valuable information that would be needed in further pre-implementation design iterations, to inform curricular (re)design, to plan for teachers’ pre-service training and professional development and to begin to build teaching resources in preparation for the actual implementation further downstream.

7 Discussion and conclusion

This study has considered the design of educational technology in light of the posited introduction of a humanoid educational service robot into local primary school classrooms. It has argued that pre-implementation design is a neglected aspect of implementation and it has demonstrated how it could be improved using a combination of powerful frameworks for alignment. This chapter summarises this process, discusses its implications for implementation design more generally and makes various recommendations about the local potential for the robot and how educational institutions could plan for its use.

The aim of the research was to show how pre-implementation design could be optimised in the case of this particular robot. The study was conducted using design based research (DBR) methodology, which allowed the researcher to involve local teachers and school students and university education technology developers directly in the design process. DBR utilises a range of methodologies; however, in this case it incorporated three lenses: a participatory design approach that provided input to the design of a learning activity that would enable the researcher to evaluate the robot's potential use, cyclical evaluation of the learning activity using technology design principles, and the further design and user testing of the activity using computational practice pedagogical frameworks. Two iteration cycles were conducted to evaluate the potential of the robot using the prototype learning activity.

This chapter presents a summary of what was learnt in terms of the four steps of DBR and how they addressed the key research question and sub-questions. In this regard, the discussion revolves around a deeper analysis of the study in terms of each of the three lenses described above. This discussion is followed by an account of the study's limitations and key conclusions that can be drawn, including the study's contribution to the field. A final reflection on avenues for further research will follow at the end of the chapter.

7.1 Summary and further discussion

This project followed the overarching four-step DBR methodology. **Step 1** involved defining the problem in theoretical and practical terms, before the initial analysis was undertaken in Step 2. This led to the formulation of the main research questions that would be addressed by this thesis:

How can education technology implementation design be optimised for the introduction of humanoid educational service robots in the classroom?

The associated sub-questions were:

1. *How can teachers and researchers work together to optimise the implementation design for the introduction of a humanoid service robot into a primary school classroom?*
2. *How can the potential of the humanoid educational service robot be evaluated using design principles?*
3. *What factors need to be addressed in the pre-implementation evaluation process?*

Using a participatory design approach ensured that design decisions made in **DBR Step 2** was informed by teachers' needs and experiences. In DBR, Step 2 involves analysis of the central problem. Chapter 4 described how the researcher worked with local teachers in this step seeking information by way of questionnaires and interviews, and synthesising it using the TPACK framework. This information was further distilled via thematic analysis to answer sub-question 1 (*How can teachers and researchers work together to optimise the implementation design for the introduction of a humanoid service robot into a primary school classroom?)* by providing the following initial design requirements for the classroom implementation of the robot:

1. The humanoid robot should be able to be programmed to provide a flexible learning environment for different kinds of learning activities and different kinds of students.
2. The robot should be able to provide strong support for student-centred learning.
3. The robot's interactive capability should be utilised in learning activities.
4. The robot should be engaging and fun to use.
5. Learning activities should be aligned with relevant curriculum
6. The robot could fit with language and literacy or programming areas of curriculum.
7. Teachers may need programming expertise to make the robot flexible/interactive to use in the classroom.
8. Teachers would require training and time allowance for preparation before implementing this robot in their classroom practice
9. The robot would need to be robust, not prone to malfunction, and able to be used with limited access to technical support.

As described in Chapters 5 and 6, the project was able to deliver on requirements 2, 3 (in part), 4, 5 and 6 (in part). Requirements 1, 7 and 9 were shown to be problematic in ways that were discussed in Chapter 5. Requirement 8 was therefore revealed to be of critical importance. The direction that training should take was not explored in the project's evaluation process. In a recent study that used the NAO robot to teach computational thinking to Grade 5 students, Chen et al. (2017) reported that the teachers in the study were given a one-day workshop on the use of the robot; however further investigation would need to be undertaken and guidelines for training developed before the robot could be implemented in a local environment.

DBR Step 3 involves the development of solutions, often in the shape of a prototype intervention that can be further evaluated and iterated. Chapter 5 described the language skills based learning activity that was first developed as a possible means of evaluating the potential of the robot. **DBR Step 4** involves testing the intervention, which allowed the project to address the second research sub-question: *How can the potential of the humanoid educational service robot be evaluated using design principles?*.

The study showed where DBR and technology design principles can profitably overlap in the education sphere, in that the evaluation strategies throughout were a combination of current DBR methods for systematically evaluating educational interventions and design principles for systematically evaluating technology design. Early evaluation of the first learning activity design showed that it would challenge teachers' programming expertise to an untenable degree and that furthermore, the robot was still not currently optimised for pedagogies that would require it to meaningfully converse about language. This meant that the implementation design would no longer fit the initial design requirements, so the learning activity had to be redesigned to mitigate this risk before being tested with children.

The new design still took into account the requirements developed in Step 2, but it switched from language skills to computational practice in terms of its curriculum alignment. Focusing on the goal of enhancing computational practice using robotic technology meant the implementation design could draw on recent findings in the literature related to deep constructionist learning using robots. This helped provide answers to the third research sub-question: *What factors need to be addressed in the pre-implementation evaluation process?,* in that Chapter 6 described the range of implications the redesign of the learning activity had for the evaluation of the potential of the robot in terms of both computational literacy curriculum and computational practice pedagogies.

The study found that many of the factors that need to be addressed are contingent upon curriculum-related choices in that each subject area calls for certain pedagogies. This means that whatever education content domain seems promising with respect to the technology, there will almost certainly be a pedagogical framework associated with it. Pre-implementation planning should clearly factor these into the design; however the need for this has often been ignored, and it has generally been airily assumed that the affordances of new technology can always be 'matched' to (usually unspecified) pedagogies. This study shows, however, that although pedagogy is more flexible than curriculum, it still needs a great deal of thought in terms of alignment, which is where the TPACK framework has shown its usefulness.

The redesigned activity was tested in a user laboratory with children in pairs and groups of three and observations of the children's interactions with the robot focused on their learning in this context. In particular, the researcher evaluated whether the activity with the robot could help the children acquire a set of 'approaches' that would stand them in good stead as they developed their computational literacy. These approaches were derived from recent research on the emerging curriculum area of 'computational practice', which this study argued is more applicable to primary school teaching than the more widely known domain of 'computational thinking'.

The evaluation process showed that the robot's affordances would indeed lend themselves to the development of computational practice in primary school children in the local context with some caveats. In particular, the robot's physical limitations with regard to 'tinkering' and 'remixing' practices meant that its use would need to be augmented with other technological options to get the most out of it in a curricular context. Age-related factors were shown to play an important role in evaluating the potential of the robot. Children's level of prior experience with computational and robotic technology also emerged as a factor in the study. However the extent of this as a differentiator might be expected to diminish as computational literacy is more fully integrated into the K-12 curriculum, especially in consideration of the role that primary schooling should play in the development of good computational practice in children from an early age.

The evaluation described in Chapter 6 showed how good *pre*-implementation design can pave the way for better implementation by anticipating how the use of the technology could play out in terms of students' learning trajectories. Previous studies have not focused on this much, partly because the use of educational service robots is still at an early stage and the technology is expensive to acquire. In addition, research has involved small-scale explorations with the implicit expectation that curriculum will emerge on an ad hoc basis. This is clearly the other extreme from the usual top-down education technology implementation strategies, where 'waterfall' design means that not much is known about the impact of the technology until it 'hits the classroom', so to speak. However, as Roschelle et al. (2010) urge, that gulf must be bridged in pre-implementation design, and this study demonstrates how an education technology implementation design team could extrapolate curricular implications relatively early in the design process.

7.2 Limitations of the study

There were some limitations to this study, which included the fact that the sizes of the samples of teachers and students were fairly small and restricted to a relatively small region. This means that there are aspects of how the teachers' technological experience and the children's computational practice affected the implementation design that do not lend themselves to widely generalizable conclusions. However, this is in keeping with the localized focus of DBR and its qualitative underpinnings, as noted in the literature review. The posited integrated use of multiple alignment systems may be viewed as a strength, but it also has limitations due to the time required and its complexity. There were also issues of prioritization between the three main TPACK dimensions, as well as between the design approaches used in education and technology development more generally. The interdisciplinary nature of the research topic also added a layer of complexity and time pressure.

Researchers have noted that DBR is hard to fit with a typical PhD-length project and this was indeed found to be the case in the context of this study. As Anderson & Shattuck (2012) note, it is difficult to predict when the research cycles will be completed and making a meaningful contribution using this methodology means undertaking an initially unpredictable number of iterations. In this study, testing with children both in a user laboratory and in a classroom were initially envisaged; however, problems arising from the first prototype iteration meant that only the first of these was achieved. This meant that there were aspects of the children's behaviour that could be absent in classroom settings or play out in ways that were not captured in the observational study. For this reason, further investigation of the ways the humanoid robot could enhance computational practice discussed in Chapter 6 would need to be situated in real-world classroom contexts.

7.3 Contribution to educational technology implementation design

In education, as in many institutional arenas, the introduction of new technology is often driven by technological advancement and occasionally by manufacturing 'hype'. Pre-implementation design, therefore, needs to evaluate the 'state of advance' and cut through the hype, and it does this through a spiralling process of alignment checking. McKenney and Reeve (2013) note that implementation design can look to curriculum theory to provide a model for this kind of multi-faceted alignment, and they also provide resource-based listings of the kinds of elements that relate to curriculum alignment. This thesis shows that alignments related to educational technology do indeed need careful consideration, not only in relation to *curriculum*, but also in a range of other ways that may not be initially obvious, especially to technology manufacturers, who are often unaware of the overlapping complexities in school systems, as well as more local constraints. This is where DBR can come in.

However, DBR is often only undertaken when the technology has already been purchased by enthusiastic technology leaders, usually by conducting preliminary classroom 'trials' with equally enthusiastic 'reform-focused' teachers (Roschelle et al., 2010). As shown in the literature, later failures of technology to deliver on the promises intimated by these kinds of studies are often laid at the door of teachers' lack of 'belief', 'acceptance' or 'technological fluency'. This project shows how pre-implementation design could help ameliorate these unhelpful tendencies and avoid associated costly mistakes, both monetary and in terms of human resources. In particular, the TPACK framework offers a way to evaluate alignment between teachers' technological expertise and the technology in question and to use this information to retire risk early in this regard, either by being flexible about the use of the technology (as was the case here) or by planning for professional development for teachers and greater technical support (or combinations of these elements depending on the local context).

The TPACK framework has been used in previous studies to ascertain the need for pre-service training or professional development and to inform its content—in this sense teachers' development is at its heart. TPACK can also be used to evaluate interventions (Bunz, 2016). In this thesis, however, it has been used in a novel way to organise the DBR process that underpins the pre-implementation evaluation of the educational service robot. In particular, the TPACK framework is used here as a means to organise, classify and deploy the kind of rich information that arises from the local context and that should always be used to inform implementation design.

To evaluate the potential use of the robot in terms of the requirements listed above, a prototype learning activity was created in two iteration cycles. This brought into play the second powerful alignment system incorporated into this study. This was the use of technology design methods, which offer a framework for iterating technology projects. In particular, this study drew on methods derived from software engineering and human-computer interaction such as prototyping, agile 'test as you go' procedures and methods for user interface testing, such as scenario based elicitation.

The third powerful alignment system utilised in this project involved a synthesis of recent computational practice pedagogical frameworks. This allowed the researcher to evaluate the pedagogical potential of the robot by undertaking purposeful alignment between the affordances of the robot and key educational goals. This strategic evaluation process drew on research that shows that educational technology must have a very clear purpose in terms of learning trajectories and educational outcomes; implementation that takes place without this kind of clarity and alignment with educational goals is doomed to failure. Combining these three powerful systems of alignment—TPACK knowledge, technology design principles and a relevant pedagogical framework—provides a blueprint for educational technology pre-implementation design; DBR grounds the planning in the local context.

More specific and localised lessons learnt from the integration of these three powerful systems of alignment are encapsulated in the following guidelines distilled from the project:

- Engage teachers in participatory design and classify their input using the TPACK framework
- Prototype a learning activity based on this input to evaluate the technology's potential
- Retire technological risk early
- Consider curricular alignment both early and late
- Evaluate at all stages using current relevant pedagogical frameworks
- Test with prospective users, initially in controlled settings
- Use the results of user testing to design curricular activity systems, assessment instruments, teacher training guidelines and other resources
- Trial these in classrooms and iterate them as necessary before implementation.

Computational practice and its associated pedagogies provide avenues for further research arising from this project. The work done here could provide the basis for testing the guidelines described above, as well as evaluating the set of alignments described in Chapter 6 in real classroom settings. Further investigation into the 'curriculum trajectory' approaches described in Chapter 6 is also envisaged.

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9 A1. Ethics Approval for This Research

This appendix includes three attachments related to the granted ethics approval for the work reported in this thesis:

- SUHREC Project 2014/154 Ethics Clearance
- Catholic education office
- SUHREC Project 2015/300 Ethics Clearance

The email received indicating approval to carry out this research.

All conditions pertaining to this clearance were properly met, and annual reports have been submitted each year as per the required reporting standards.

Astrid Nordmann | Vivienne Farrell; RES Ethics; Kaberi Naznin; Karola von Baggo | 14/08/2014

SHR Project 2014/154 - Ethics clearance

To: Dr Vivienne Farrell, FSET

SHR Project 2014/154 Exploration of the use of emerging technologies in education by employing methods of constructivism from the perspective of teachers
Dr Vivienne Farrell; Kaberi Naznin; Dr Karola Von Baggo; Dr Linton Woodward FSET
Approved duration from 15-08-2014 to 14-08-2015 [adjusted]

I refer to the ethical review of the above project protocol by a Subcommittee (SHESC1) of Swinburne's Human Research Ethics Committee (SUHREC). Your responses to the review, as per the email sent on 05 August and 14 August 2014 (with attachments), were put to the Subcommittee delegate for consideration.

I am pleased to advise that, as submitted to date, the project may proceed in line with standard on-going ethics clearance conditions here outlined.

- All human research activity undertaken under Swinburne auspices must conform to Swinburne and external regulatory standards, including the current *National Statement on Ethical Conduct in Human Research* and with respect to secure data use, retention and disposal.

- The named Swinburne Chief Investigator/Supervisor remains responsible for any personnel appointed to or associated with the project being made aware of ethics clearance conditions, including research and consent procedures or instruments approved. Any change in chief investigator/supervisor requires timely notification and SUHREC endorsement.

- The above project has been approved as submitted for ethical review by or on behalf of SUHREC. Amendments to approved procedures or instruments ordinarily require prior ethical appraisal/clearance. SUHREC must be notified immediately or as soon as possible thereafter of (a) any serious or unexpected adverse effects on participants any redress measures; (b) proposed changes in protocols; and (c) unforeseen events which might affect continued ethical acceptability of the project.

- At a minimum, an annual report on the progress of the project is required as well as at the conclusion (or abandonment) of the project. Information on project monitoring, self-audits and progress reports can be found at: http://www.research.swinburne.edu.au/ethics/human/monitoringReportingChanges/

- A duly authorised external or internal audit of the project may be undertaken at any time.

Please contact the Research Ethics Office if you have any queries about on-going ethics clearance. The SHR project number should be quoted in communication. Researchers should retain a copy of this email as part of project recordkeeping.

Best wishes for the project.

Yours sincerely,
Astrid Nordmann
SHESC1 Secretary

Dr Astrid Nordmann
Research Ethics Executive Officer
Swinburne Research (H68)
Swinburne University of Technology
PO Box 218, Hawthorn, VIC 3122
Tel: +613 9214 3845
Fax: +613 9214 5267
Email: anordmann@swin.edu.au

Catholic Education Office
Archdiocese of Melbourne

GE14/0009 Project #2045 Farrell
27 October 2014

Dr Vivienne Farrell
Swinburne University
Higher Education Office H20
Hawthorn VIC 3122

Dear Dr Farrell

I am writing with regard to your research application received on 18/09/2014 concerning your forthcoming project titled, *Exploration of the use of emerging technologies in education by employing methods of constructivism from the perspective of teachers.* You have asked approval to involve a Catholic school in the Archdiocese of Melbourne, as you wish to involve teachers.

I am pleased to advise that your research proposal is approved in principle subject to the eight standard conditions outlined below.

1. The decision as to whether or not research can proceed in a school rests with the school's principal, so you will need to obtain approval directly from the principal of the school that you wish to involve. You should provide the principal with an outline of your research proposal and indicate what will be asked of the school. A copy of this letter of approval, and a copy of notification of approval from the organisation's/university's Ethics Committee, should also be provided.

2. A copy of the approval notification from your institution's Ethics Committee must be forwarded to this Office, together with any modifications to your research protocol requested by the Committee. You may not start any research in Catholic Schools until this step has been completed.

3. A *Working with Children* (WWC) check – or registration with the Victorian Institute of Teaching (VIT) – is necessary for all researchers visiting schools. Appropriate documentation must be shown to the principal before starting the research in the school.

4. No student is to participate in the research study unless s/he is willing to do so and informed consent is given in writing by a parent/guardian.

James Goold House, 228 Victoria Parade, East Melbourne VIC 3002 Tel: (+61 3) 9267 0228 Fax: (+61 3) 9415 9325
Correspondence: PO Box 3, East Melbourne VIC 8002 Email: director@ceomelb.catholic.edu.au **www.ceomelb.catholic.edu.au**
ABN 85 176 448 204

5. Any substantial modifications to the research proposal, or additional research involving use of the data collected, will require a further research approval submission to this Office.

6. Data relating to individuals or the school are to remain confidential.

7. Since participating schools have an interest in research findings, you should consider ways in which the results of the study could be made available for the benefit of the school community.

8. At the conclusion of the study, a copy or summary of the research findings should be forwarded to the Catholic Education Office Melbourne. It would be appreciated if you could submit your report in an ***electronic format*** using the email address provided below.

I wish you well with your research study. If you have any queries concerning this matter, please contact Ms Shani Prendergast of this Office.

The email address is apr@ceomelb.catholic.edu.au

Yours sincerely

Anna Rados
MANAGER ANALYSIS, POLICY & RESEARCH

Keith Wilkins on behalf of RES Ethics | Vivienne Farrell; Kaberi Naznin; RES Ethics; + 1 | 19/11/2015

SHR Project 2015/300 Ethics Clearance

To: Dr Vivienne Farrell/Ms Kaberi Naznin, FSET
Dear Viv and Kaberi
SHR Project 2015/300 Using a Humanoid Robot to introduce primary aged students to programming concepts
Dr Vivienne Farrell, FSET; Ms Kaberi Naznin, Dr Karola Von Baggo, Dr Clinton Woodward
Approved Duration: 19-11-2015 to 30-11-2016 [Adjusted]
I refer to the ethical review of the above project protocol by Swinburne's Human Research Ethics Committee (SUHREC). Your responses to the review, as emailed on 17 November 2015 with attachments, were put to the SUHREC delegate for consideration.
I am pleased to advise that, as submitted to date, the project may proceed in line with standard on-going ethics clearance conditions outlined below.

- All human research activity undertaken under Swinburne auspices must conform to Swinburne and external regulatory standards, including the *National Statement on Ethical Conduct in Human Research* and with respect to secure data use, retention and disposal.
- The named Swinburne Chief Investigator/Supervisor remains responsible for any personnel appointed to or associated with the project being made aware of ethics clearance conditions, including research and consent procedures or instruments approved. Any change in chief investigator/supervisor requires timely notification and SUHREC endorsement.
- The above project has been approved as submitted for ethical review by or on behalf of SUHREC. Amendments to approved procedures or instruments ordinarily require prior ethical appraisal/clearance. SUHREC must be notified immediately or as soon as possible thereafter of (a) any serious or unexpected adverse effects on participants and any redress measures; (b) proposed changes in protocols; and (c) unforeseen events which might affect continued ethical acceptability of the project.
- At a minimum, an annual report on the progress of the project is required as well as at the conclusion (or abandonment) of the project. Information on project monitoring and variations/additions, self-audits and progress reports can be found on the Research Intranet pages.
- A duly authorised external or internal audit of the project may be undertaken at any time.

Please contact the Research Ethics Office if you have any queries about on-going ethics clearance, citing the Swinburne project number. A copy of this email should be retained as part of project record-keeping.
Best wishes for the project.
Yours sincerely
Keith

Keith Wilkins
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10 A2. SUHREC Project 2014/154

This appendix lists for the teacher's input cycle which I described in Chapter 4.

- Letter of request to principal
- Plain Language Statement (PLS) describing research- for participant
- Informed Consent

First Investigator: Dr. Vivienne Farrell, Senior Lecturer, E-mail: vfarrell@swin.edu.au.
Chief Investigator: Dr. Karola von Baggo, lecturer. E-mail: kvonbaggo@swin.edu.au.
Associate Investigator: Dr. Clinton Woodward, lecturer. E-mail: cwoodward @swin.edu.au
Main Student Investigator: Kaberi Naznin, PhD student, knaznin @swin.edu.au
Faculty of Science, Engineering and Technology (FSET),
Swinburne University of Technology.

Letter of request to principal

Swinburne University of Technology
Research Project Title: Exploration of the use of emerging technologies in education by employing methods of constructivism from the perspective of teachers.

First Investigator: Dr. Vivienne Farrell
Chief Investigator: Dr. Karola von Baggo
Associate Investigator: Dr. Clinton Woodward
PhD Student Investigator: Kaberi Naznin

To
Principal's name
The Principal,
School Name,
Address.

Dear Sir/Madam,

Allow me to take the opportunity to introduce myself. I am Kaberi Naznin, a PhD student from Swinburne University of Technology. My colleagues and I are conducting research on "exploring the use of emerging technologies in education by employing methods of constructivism". The main goal of this research is to explore new ways of engaging students using emerging technology in education while improving the learning outcomes of students. For this study we are employing an exciting development in the human android robots, the Nao Robot, which enables a more natural interaction between humans and technology. The Nao Robots are on display at Scienceworks through their current exhibition on personal robots.

Teachers incorporating humanoid robots in their programs are finding many new ways of engaging children. In particular, the NAO robot has been successful in increasing the interest of girls in STEM (Ruzzenente et all., 2012) and with communication and motivation of autistic children (Shams Uddin et all., 2012). The Nao robot is currently being used in many disciplines with software being developed by academics and children. The Nao development interface is relatively easy to use and enables diversity in its applications for children to program as it is designed in response to the child's imagination. Higher level benefits to students include areas such as writing skills, dexterity, logic, organisational, project management and team work to name a few. We are fortunate to have acquired NAO robots for research. and would welcome your school to participate in our study while providing an in-service for your staff and incursion for your students. It is anticipated that from the collated outcomes of the research staff will gain an improved understanding of teacher and student perceptions to observing possible variations in the learning processes using emerging technologies. It is also expected that the findings of this study will contribute to the emerging literature on contemporary language learning spaces.

The first stage of this project is to undertake a user needs based analysis of integration of the Nao robot in the teaching/learning space to enable effective learning. Teachers involved in this study would in the first instance, be able to contribute to the development of literacy based programs, through our discussions of the learning processes, technology acceptance of staff and students, difficulties encountered in current teaching practices. Through this study, teachers will have an opportunity to identify and formulate future teaching methods for effectiveness of learning using emerging technologies. Further we would welcome the opportunity for staff to engage with this university research project in which their voice will be valued and contribute meaningfully to the outcomes and recommendations of the project.

We anticipate that by engaging with your experienced staff we will be able to design new and engaging ways to promote student learning. In this study, we will ask teachers about their teaching background and philosophies, and will show them a video of the Nao Robot in a learning environment to demonstrate its physical capabilities and encourage them to consider

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Associate Investigator: Dr. Clinton Woodward, lecturer, E-mail: cwoodward @swin.edu.au
Main Student Investigator: Kaberi Naznin, PhD student, knaznin @swin.edu.au
Faculty of Science, Engineering and Technology (FSET),
Swinburne University of Technology.

how a humanoid robot may fit into their classroom. The collated data recorded during interview sessions will be used in preparation of a PhD thesis, and may be published in Conference and Journal papers.

We have received permission from the Swinburne Ethics Approval Committee, Swinburne University of Technology and Catholic education body.

All data from interview sessions with teachers are confidential any other person including yourself or any educational staff (e.g., other teachers, education bodies as per the requirements of Swinburne Universities ethics committee. We will also not refer to what other staff have said in our interviews. However, we would be delighted to forward to you any papers published from the collated results of this study.

In relation to this project, we would therefor request from you the following support:

- Permission to approach your teachers for the purpose of recruiting participants for our study (email invitation and/or poster on the staff notice board),
- Permission to conduct interviews on school premises (we find that interviewing people in the environment in which they work offers a better, more contextual results).
- Approximately 1 hour worth of time from the teachers that agree to take part in the study.

We eagerly await your positive response to explore new way for engaging students in the classroom using emerging technology. If you have further queries or require clarification of this project, or would like to be involved in this project by enabling us to conduct interviews in your school, please reply via email to myself, Kaberi Naznin, at knaznin@swin.edu.au.

Thankyou for your assistance and look forward to further engagement.

Best regards,

Kaberi Naznin
Faculty of Science, Engineering and Technology,
Swinburne University of Technology
Email: knaznin@swin.edu.au

References:

Ruzzenente, M., Koo, M., Nielsen, K., Grespan, L., & Fiorini, P. (2012, April). A review of robotics kits for tertiary education. In Proceedings of International Workshop Teaching Robotics Teaching with Robotics: Integrating Robotics in School Curriculum (pp. 153-162).

Shamsuddin, S., Yussof, H., Ismail, L., Hanapiah, F. A., Mohamed, S., Piah, H. A., & Ismarrubie Zahari, N. (2012, March). Initial response of autistic children in human-robot interaction therapy with humanoid robot NAO. In Signal Processing and its Applications (CSPA), 2012 IEEE 8th International Colloquium on (pp. 188-193). IEEE.

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First Investigator: Dr. Vivienne Farrell, Senior Lecturer, E-mail: vfarrell@swin.edu.au.
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Associate Investigator: Dr. Clinton Woodward, lecturer, E-mail: cwoodward @swin.edu.au
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Appendix B: Plain Language Statement (PLS) describing research- for participant

Research project: Exploration of the use of emerging technologies in education by employing methods of constructivism from the perspective of teachers.

Thank you for your interest in supporting this project on "Exploration of the use of emerging technologies in education by employing methods of constructivism from the perspective of teachers".

The purpose of this research is to conduct interviews with primary and secondary school teachers to determine your responses and attitudes to using technology in the classroom. In the first instance your opinions on gaining maximum benefit from using the NAO robot to assist with language learning will be collected. This project is being undertaken by PhD student Kaberi Naznin and Dr Vivienne Farrell, Dr. Karola von Baggo and Dr. Clinton Woodward from Swinburne University of Technology.

Participating in this study will involve an interview of up to one hour. During this time you will be asked questions about your teaching practices that you may find challenging and those which are of value. The interview will be in two parts:

Part 1: Your teaching experience and approach to teaching

In this part of the interview we will ask you questions about your teaching experience. This will help us interpret the data we collect for the second part of the interview.

Part 2: Imagining a future with the Nano robot

In this part of the interview we present a video of a NAO robot, demonstrating some of the programs our students have written. This video and the links below are to encourage you to consider how you may imagine NAO being used in the classroom. Some possible examples are using NAO robot in education can be found by the following links.

- Good for girls in STEM; https://www.youtube.com/watch?v=7k6WJaEgTRU
- Alderbran's advertising for education, it focuses mainly on programming, robotics and engineering rather than using programs for classroom teaching; http://www.teq.com/nao-robot
- For autistic children in the classroom; http://www.cnet.com/au/news/interactive-robot-aids-autistic-kids-in-the-classroom/
- NAO Robot used in classroom: http://www.youtube.com/watch?v=NURFYWlyC24
- Community website in education: https://community.aldebaran-robotics.com/
- Lots of NAO videos on youtube; https://www.youtube.com/user/AldebaranRobotics/videos
- Bruce Springsteen and maze projects using NAO robots have been developed by the final year students of Swinburne University of Technology.

The interview will be carried out by Kaberi Naznin. An audio recording will be made of the interview. If you do not wish to have record your voice, please let her know.

The data recorded during your session will be used in preparation of a PhD thesis, and may be published in Conference and Journal papers. You will not be personally identified in any of the data reported. In addition, any students or colleagues you refer to during the interview will not be identified. The content of our interviews will not be discussed with yourself or any other educational staff (e.g., other teachers, your principal, education bodies etc.). However, we would be delighted to forward to you any papers published from the collated results of this study.

First Investigator: Dr. Vivienne Farrell, Senior Lecturer, E-mail: vfarrell@swin.edu.au.
Chief Investigator: Dr. Karola von Baggo, lecturer, E-mail: kvonbaggo@swin.edu.au.
Associate Investigator: Dr. Clinton Woodward, lecturer, E-mail: cwoodward @swin.edu.au
Main Student Investigator: Kaberi Naznin, PhD student, knaznin @swin.edu.au
Faculty of Science, Engineering and Technology (FSET).
Swinburne University of Technology.

You are free to end your session at any time without giving a reason, or you may tell us your reasons if you wish.

We ask that you next read and sign our consent form.

If you have any questions about this document or the consent form or anything else related to this study, please do not hesitate to ask (details below). We thank you for helping us in this project.

If you have any concerns please contact:

Research Ethics Office
Swinburne Research (H68)
Swinburne University of Technology
P O Box 218, HAWTHORN VIC 3122.
Phone: (03) 9214 5218
Fax: (03) 9214 5267
Email: resethics@swin.edu.au

Please feel free to keep this sheet for your own reference.

Dr. Vivienne Farrell, Senior Lecturer, E-mail: vfarrell@swin.edu.au.
Dr. Karola von Baggo, lecturer, E-mail: kvonbaggo@swin.edu.au.
Dr. Clinton Woodward, lecturer, E-mail: cwoodward @swin.edu.au
Kaberi Naznin, PhD student, knaznin @swin.edu.au
Faculty of Science, Engineering and Technology (FSET),
Swinburne University of Technology.

Appendix C: Informed Consent

Swinburne University of Technology
Research Project Title: Exploration of the use of emerging technologies in education by employing methods of constructivism from the perspective of teachers.
Principal Investigator(s): Dr. Vivienne Farrell

I am over the age of 18 and consent to participate in the project named above. I have read and understood the information provided to me about the nature of the research project: "Exploration of the use of emerging technologies in education by employing methods of constructivism from the perspective of teachers". Any questions, I have asked have been answered to my satisfaction.

In relation to this project, please circle your response to the following:

☐	I agree to be interviewed by the researcher	Yes	No
☐	I agree to allow the interview to be recorded by electronic device	Yes	No
☐	I agree to allow my voice to be recorded by recorder	Yes	No
☐	I agree to make myself available for further information if required	Yes	No
☐	I agree to complete questionnaires asking me about teaching experiences	Yes	No

I acknowledge that:

(a) my participation is voluntary and that I am free to withdraw from the project at any time without explanation;

(b) the Swinburne project is for the purpose of research and not for profit;

(c) any identifiable information about me which is gathered in the course of and as the result of my participating in this project will be (i) collected and retained for the purpose of this project and (ii) accessed and analysed by the researcher(s) for the purpose of conducting this project;

(d) Only the team nominated at the top of this form will have access to audio recording made during interview session.

(e) my anonymity is preserved and I will not be identified in publications or otherwise without my express written consent.

By signing this document I agree to participate in this project.

Name of Participant: ....

Signature & Date: ....

Faculty of Science, Engineering and Technology,
Swinburne University of Technology,
PO Box 218, Hawthorn, Victoria, 3122, Australia.

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This appendix lists for the second iteration cycle, which was used in Chapter 6.

- Plain Language Statement (PLS) describing research- for parents
- Informed Consent
- Demographic Questionnaire
- Demographic Data

First Investigator: Dr. Vivienne Farrell, Senior Lecturer, E-mail: vfarrell@swin.edu.au.
Chief Investigator: Dr. Karola von Baggo, lecturer, E-mail: kvonbaggo@swin.edu.au.
Associate Investigator: Dr. Clinton Woodward, lecturer, E-mail: cwoodward @swin.edu.au
Main Student Investigator: Kaberi Naznin, PhD student, knaznin @swin.edu.au
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Swinburne University of Technology.

Appendix A: Plain Language Statement (PLS) describing research- for parents

Research project: Using a Humanoid Robot to introduce primary aged students to programming concepts.

Thank you for your interest in supporting this project on "Using a Humanoid Robot to introduce primary aged students to programming concepts."

We welcome the opportunity to offer your child to spend time with NAO the Humanoid Robot. NAO is a fully programmable robot that can walk, talk, dance and many other actions. During your child's time with NAO they will see many of the basic actions it can do and have a chance to create their own sequence of actions for NAO to do. Your child will be in a group of 2-3 so will have a good opportunity for a hands-on experience.

An interaction between a child and Humanoid NAO Robot

(http://today.uconn.edu/2010/08/robot-speaks-the-language-of-kids/)

We are interested to see how children interact with the humanoid robot and the ways in which they respond to concepts of introductory programming using NAO. After the demonstration of NAO's capabilities and programming tools we will observe and record their responses and attitudes to the humanoid robot. This data will help us to better understand how NAO can be used to encourage and educate children in the classroom.

This project is being undertaken by PhD student Kaberi Naznin and Dr Vivienne Farrell, Dr. Karola von Baggo and Dr. Clinton Woodward from Swinburne University of Technology. The testing will be carried out by Kaberi Naznin.

A video recording will be made of the interview. If you do not wish to have record your child's face, please let us know.

The data recorded during the test session will be used in preparation of a PhD thesis, and may be published in Conference and Journal papers. You child will not be personally identified in any of the data reported. In addition, any students they refer to during the interview will not be identified. The content of our interviews will not be discussed with yourself, or your child, or other students, or other educational staff (e.g., other teachers, school principal, education bodies etc.). However, we would be delighted to forward to you any papers published from the collated results of this study.

First Investigator: Dr. Vivienne Farrell, Senior Lecturer, E-mail: vfarrell@swin.edu.au
Chief Investigator: Dr. Karola von Baggo, lecturer, E-mail: kvonbaggo@swin.edu.au
Associate Investigator: Dr. Clinton Woodward, lecturer, E-mail: cwoodward @swin.edu.au
Main Student Investigator: Kaberi Naznin, PhD student, knaznin @swin.edu.au
Faculty of Science, Engineering and Technology (FSET),
Swinburne University of Technology.

Participating in this study will involve up to one and half hours. Your child is free to end his/her session at any time without giving a reason, or he/she may tell us his/her reasons if he/she wishes.

We ask that you next read and sign our consent form.

If you have any questions about this document or the consent form or anything else related to this study, please do not hesitate to ask (details below). We thank you for helping us in this project.

If you have any concerns please contact:

Research Ethics Office
Swinburne Research (H68)
Swinburne University of Technology
P O Box 218, HAWTHORN VIC 3122.
Phone: (03) 9214 5218
Fax: (03) 9214 5267
Email: resethics@swin.edu.au

Please feel free to keep this sheet for your own reference.

If you are interested to know more about the capabilities of the NAO robot, please visit the following links to find some possible examples how the NAO robots are using in education.

- How to Animate NAO Robot with Choregraphe, https://www.youtube.com/watch?v=Uc49qrO7P3k
- Good for girls in STEM; https://www.youtube.com/watch?v=7k6WJaEgTRU
- Alderbran's advertizing for education, it focuses mainly on programming, robotics and engineering rather than using programs for classroom teaching; http://www.teq.com/nao-robot
- For autistic children in the classroom; http://www.cnet.com/au/news/interactive-robot-aids-autistic-kids-in-the-classroom/
- NAO Robot used in classroom: http://www.youtube.com/watch?v=NURFYWlyC24
- Community website in education: https://community.aldebaran-robotics.com/
- Lots of NAO videos on youtube; https://www.youtube.com/user/AldebaranRobotics/videos
- Bruce Springsteen and maze projects using NAO robots have been developed by the final year students of Swinburne University of Technology.

Dr. Vivienne Farrell, Senior Lecturer, E-mail: vfarrell@swin.edu.au.
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Dr. Clinton Woodward, lecturer, E-mail: cwoodward @swin.edu.au
Kaberi Naznin, PhD student, knaznin @swin.edu.au
Faculty of Science, Engineering and Technology (FSET),
Swinburne University of Technology.

Appendix B: Informed Consent

Swinburne University of Technology
Research Project Title: Using a Humanoid Robot to introduce primary aged students to programming concepts.
Principal Investigator(s): Dr. Vivienne Farrell
Dr. Karola von Baggo
Dr. Clinton Woodward

1. I/We consent to my/our child/dependent here named to participate in the project named above. I have been provided a copy of the project consent information statement to which this consent form relates and any questions I have asked have been answered to my satisfaction.

Name of Child/Dependent: ....

2. ***In relation to this project, please circle your response to the following:***
   - I/We agree that my/our child can be videoed by the researcher **Yes No**
   - I/We agree to allow my/our child to answer questions about their previous experiences with technology, and their experiences during and after the session **Yes No**

3. I/We acknowledge that:
   (a) my/our child's/dependent's participation is voluntary and that s/he is free to withdraw from the project at any time without explanation;
   (b) the Swinburne project is for the purpose of research and not for profit;
   (c) any identifiable information gathered in the course of and as the result of my/our child/dependent participating in this project will be (i) collected and retained for the purpose of this project and (ii) accessed and analysed by the researcher(s) for the purpose of conducting this project;
   (d) my/our child's/dependent's anonymity is preserved and s/he will not be identified in publications or otherwise without my express written consent.
   (e) I/we aware about the data recorded during the test session will be used in preparation of a PhD thesis, and may be published in Conference and Journal papers.

By signing this document I/We agree to your child's/dependent's participation in this project.

Name of Parent(s)/Guardian: ....

Signature & Date: ....

Faculty of Science, Engineering and Technology,
Swinburne University of Technology,
PO Box 218, Hawthorn, Victoria, 3122, Australia.

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Appendix D: Demographic Questionnaire

Instructions: The purpose of this questionnaire is to find out a few things about your child. This will help us interpret our results. Please tick the option that best describes your child.

1. What is your child's gender?

   ❑ Female

   ❑ Male

2. Which grade is your child in?

   ❑Prep ❑Grade 1 ❑Grade 2 ❑Grade 3 ❑Grade 4

   ❑Grade 5 ❑Grade 6

3. What types of the technology are available to your child? Your child may use this technology at home, or/and at school?

   From the list below please choose any of the technologies your child uses and approximately how much time your child spends using this technology per day.

Technology Type	**Estimated time spent on tech at home (hours/day)**	**Estimated time spent at School (hours/day)**
Tablet (iPad, Samsung, Asus, Lenovo etc.)	0 1 2 3 4 5 5+	0 1 2 3 4 5 5+
Laptop/Desktop	0 1 2 3 4 5 5+	0 1 2 3 4 5 5+
Smart phones	0 1 2 3 4 5 5+	0 1 2 3 4 5 5+
Game platform (PlayStation, XBox, Nintendo DS, Gameboy etc.)	0 1 2 3 4 5 5+	0 1 2 3 4 5 5+
Other (please specify)	0 1 2 3 4 5 5+	0 1 2 3 4 5 5+

4. Does your child have experiences of using any of the following programming games? [Tick all that apply]

❑ Scratch

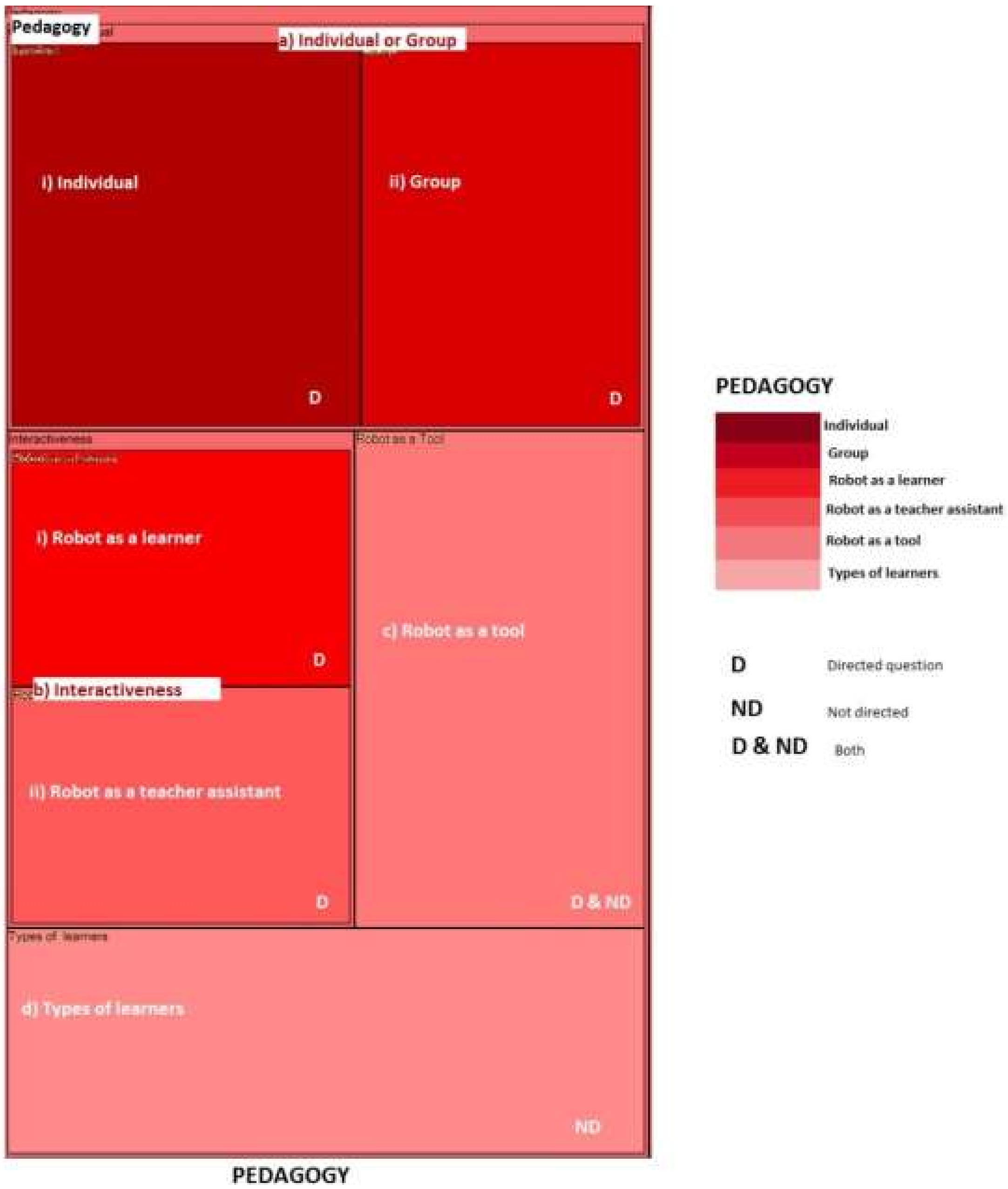
❑ Hopscotch

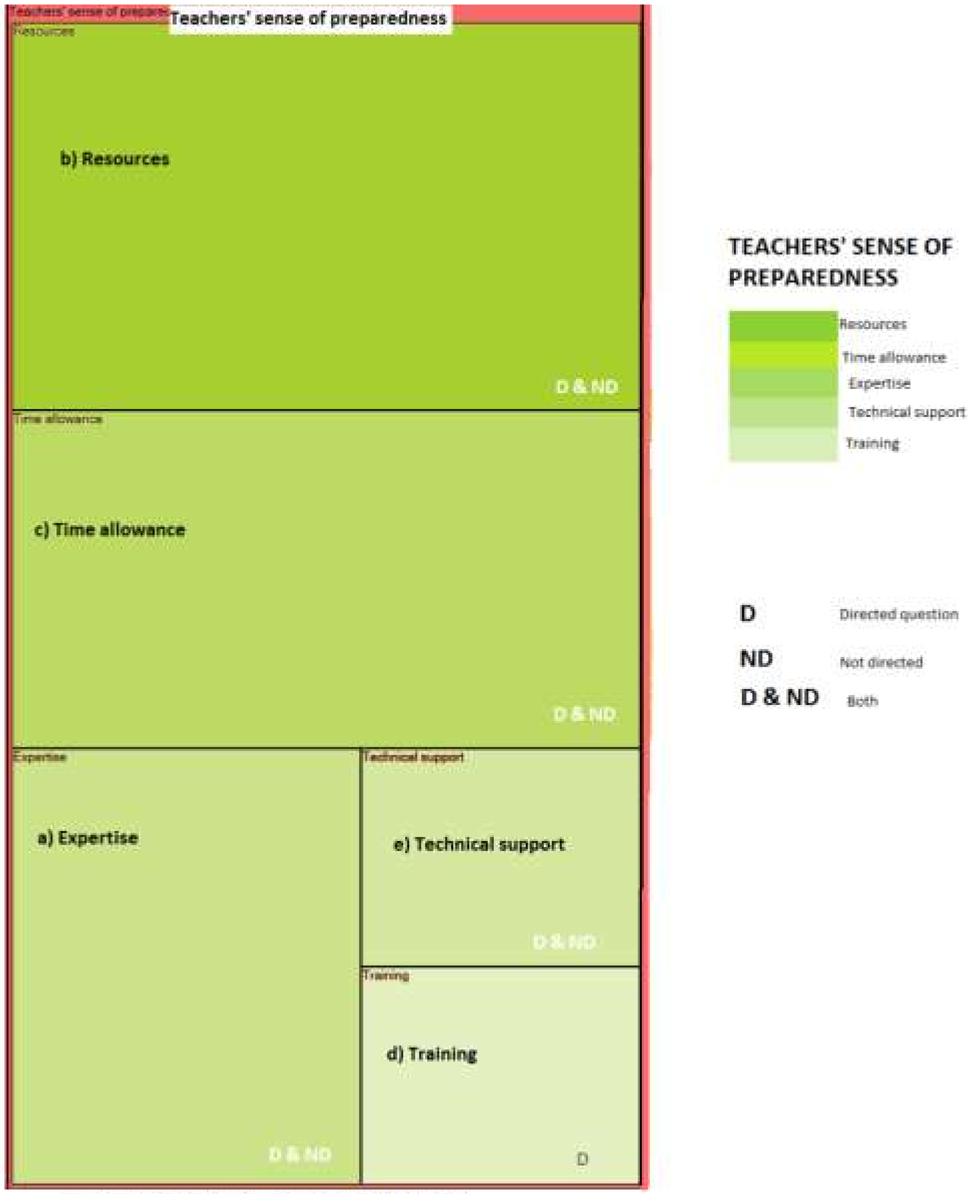
❑ Lego Mindstroms

❑ Other (please specify) ______________________________

Sessions	Sesssion and Child code	Gender	Grade	YoundAndOld	Experienced	Scratch	Hopscotch	LegoMindstorms	Other	EXPTYPE
1	1.01	1	4	2	1	0	0	0	Python	4
1	1.02	2	2	1	0	0	0	0	0	0
2	2.03	1	6	2	1	1	0	0	0	1
2	2.04	1	6	2	1	1	0	1	0	1,3
3	3.05	1	6	2	1	0	0	1	0	3
3	3.06	1	5	2	1	0	0	1	0	3
4	4.07	1	6	2	1	0	0	1	0	3
4	4.08	1	3	2	1	0	0	1	0	3
5	5.09	1	6	2	1	0	0	1	0	3
5	5.1	1	5	2	1	0	0	1	0	3
6	6.11	1	4	2	0	0	0	0	0	0
6	6.12	2	5	2	0	0	0	0	0	0
7	7.13	1	6	2	1	1	0	1	0	1,3
7	7.14	1	4	2	1	1	0	1	Pascal	1,3,4
8	8.15	1	5	2	1	1	0	0	0	1
8	8.16	1	5	2	1	1	0	0	0	1
9	9.17	1	4	2	1	1	0	0	0	1
9	9.18	1	4	2	0	0	0	0	0	0
10	10.19	1	4	2	1	0	0	0	Python	4
10	10.2	2	2	1	0	0	0	0	0	0
10	10.21	2	2	1	1	1	1	0	0	1,2
11	11.22	2	2	1	1	0	0	0	Pascal	4
11	11.23	2	3	2	0	0	0	0	0	0
12	12.24	2	2	1	0	0	0	0	0	0
12	12.25	2	3	2	0	0	0	0	0	0
13	13.26	2	4	2	0	0	0	0	0	0
13	13.27	1	4	2	0	0	0	0	0	0
13	13.28	1	4	2	0	0	0	0	0	0
14	14.29	1	2	1	0	0	0	0	0	0
14	14.3	2	2	1	0	0	0	0	0	0
15	15.31	2	2	1	0	0	0	0	0	0
15	15.32	1	2	1	0	0	0	0	0	0
15	15.33	1	3	2	0	0	0	0	0	0
16	16.34	1	4	2	1	0	0	1	0	3
16	16.35	1	4	2	1	0	0	1	0	3
17	17.36	1	2	1	0	0	0	0	0	0
17	17.37	2	1	1	0	0	0	0	0	0

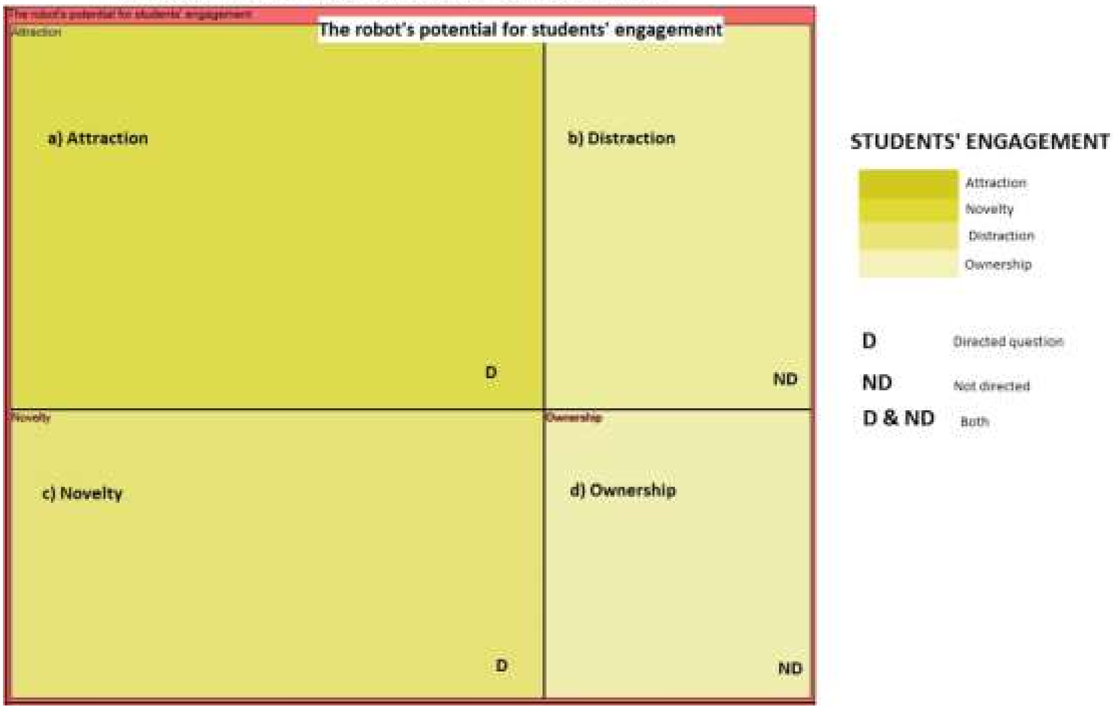
12 A4. Chapter 4: Figure 4.3 Frequencies of teachers' responses for interview questions, and coding in NVivo

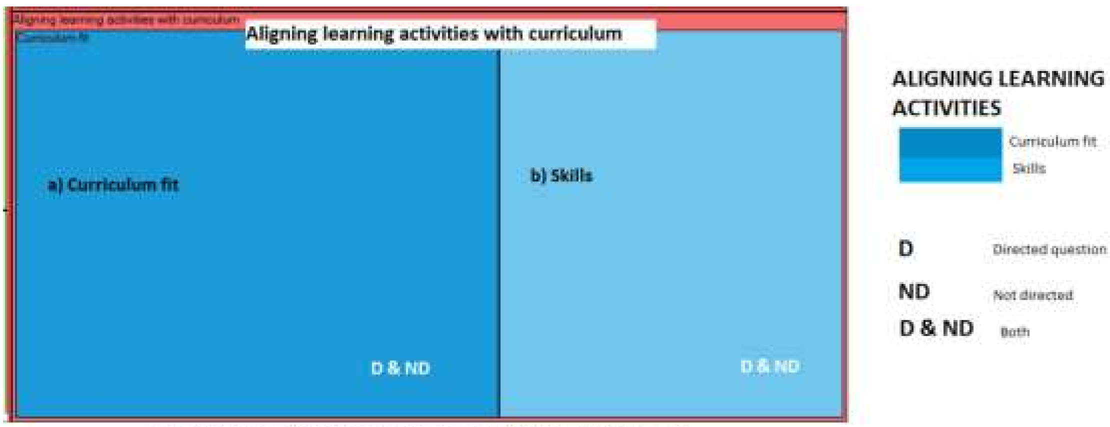




TEACHERS' SENSE OF PREPAREDNESS

THE ROBOT'S POTENTIAL FOR STUDENTS' ENGAGEMENT





ALIGNING LEARNING ACTIVITIES WITH CURRICULUM