Developmentally Appropriate Guidelines for Technology Augmented Pre-schooler Toys

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Statement of the Contribution of Others

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ABSTRACT

Use of technology by small children has accelerated in recent years which has led toy designers and manufacturers to develop technology-augmented toys. However, studies by child development specialists have shown that technology use in young children can have negative ramifications for their cognitive, social, and physical development. Toy manufacturers have sought to address this problem by combining technology with traditional toys in ways that show benefit for children by encouraging social interactions (joint play), imaginative play and educational development. At present guidelines toward technology-augmented toy design that consider both the motivations of parents and the concerns of child development experts are rare. This research aims to study the viewpoints of parents and child development experts to provide guidelines for novice toy designers and develop solutions for difficulties encountered in the design process.

As the project involved considering different perspectives from multiple stakeholders, this research adopted design-based research with Design Thinking activities. Design Thinking is a method which uses a team-based, iterative process to help designers understand users, redefine problems and create innovative solutions. Facilitated by the researcher, a small group of novice designers engaged in design thinking activities informed by stakeholder input to develop several toy design concepts with lightweight prototypes as the end output. With the use of thematic analysis, the data obtained from these activities showed that there are difficulties to be resolved in the toy design process in relation to the competing concerns of the stakeholders. These difficulties included finding the essential stakeholders' needs and defining design directions targeting those aspirations.

The findings were synthesized by the researcher with existing literature, resulting in a set of design guidelines to aid the design of electronic toys. These guidelines were then evaluated by the novice designers for feedback and were revised accordingly. The revised guidelines were then presented to both stakeholder groups to report on findings and gain insight into the participants' views regarding the project. The participants recognized that their needs are addressed in the set of guidelines and expected that the guidelines would aid in creating toys that may be advantageous to pre-schoolers' developmental processes. The production of the guidelines encourages and supports bringing parents' and children development specialists' differing viewpoints into the toy design process, which was not seen in the existing literature. The research outcomes further advocate the concept of developmentally appropriate technology use in toy design and the use of the guidelines has the potential of lowering the cost of constructing similar and/or deeper studies in both academic and industrial contexts.

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1. INTRODUCTION

1.1 Chapter overview

As new digital technologies are introduced into family homes, these technologies are increasingly being used by children. This situation poses a problem, as software and devices designed for adults may have a detrimental effect on very young children, particularly toddlers. However, technology developers often do not design with the needs of small children in mind. Additionally, information regarding the developmental needs of children in relation to technology design can be limited. To remedy this problem, the research in this thesis studied the needs from parents, child development specialists, and novice designers.

This chapter documents the context and rationale for this study. Section 1.2 describes the background of the research. The relevant studies lead to a practical problem that needs to be addressed. The literature further indicates the research gap corresponds to the practical problem. Section 1.3 describes the purpose of the study and defines the area of this study. A brief justification of general methods is also provided to indicate the approach for generating knowledge from the area of study. Section 1.4 highlights the significance of this research. Section 1.5 gives an overview of the research design including the framework and methods. Finally, section 1.6 outlines the content of the remaining chapters.

1.2 Background

This section introduces the literature about technology use and child development. A review of relevant literature regarding these topics shows the need for giving guidance in designing toys that is supportive of child development. The importance of guiding design of developmentally appropriate technology augmented toys is the foundation for this study.

Developmentally appropriate technology use (DATU) is defined as technology use that satisfies children's developmental needs and enables active, collaborative learning through children's interests (Rosen & Jaruszewicz, 2008). DATU is becoming important as technology uses become common in childhood. Nearly 70% of parents in the United States have smartphones in their homes and 44 % of parents allow their children to play with smartphones or tablets as a reward for good behaviour (Wartella et al. 2014). Although they are entertaining and interesting for young children, these electronic devices are not designed for them. Therefore, they often do not support children to develop effectively or correctly. Many studies demonstrate the lack of effectiveness of using these devices and reveal their potential harm to children (Aishworiya et al., 2018; Madigan et al., 2019). The lack of

effectiveness is shown by having minimal improvements in children's academic performance while technology use has surged in the past decade. Thus, DATU suggests that technology use should benefit children while respecting their needs and interests (Rosen & Jaruszewicz, 2008). These needs and interests can be influenced by age, individual differences, and cultural differences.

Concerns have been raised about the appropriateness of technology augmented toys for young children as these toys become more common in the market. Technology augmented toys have been integrated with new technologies that offer extra features in comparison with their traditional counterparts, as illustrated in figure1.

Figure 1: Technology augmented toy (BabyTalk) and traditional toy (Hu et al., 2016)

As use of smartphones and tablets becomes common for children, demand for traditional toys has shifted towards these devices (European Competitiveness and Sustainable Industrial Policy Consortium, 2013). Some major players in the toy industry are trying to navigate this change of demand by inventing novel toys, such as technology augmented toys (Debora et al., 2019; LEGO Group, 2019). This choice has not proceeded without debate and concern. On one hand, many studies question the benefits of technology use in childhood, including activities that are involved with technology augmented toys. On the other hand, numerous studies propose novel toy designs that claim to be more beneficial to children in comparison with their traditional counterparts (Stapleton et al., 2002; Hinske et al., 2008; Kara et al., 2013; Hu et al., 2016; Hong et al., 2019). While this thesis does not seek to resolve this debate, it focuses on the concept of DATU and creating guidelines for

toy designers who seek to design developmentally appropriate technology augmented pre-schoolers' toys and assist in conveying relevant knowledge required for the design process.

Designing **developmentally appropriate** technology augmented toys is critical to child development. Interactions with toys during play induce the most immediate impact on pre-schoolers' development (Gabbard & Krebs, 2012). Theorists suggest that play is essential for children, especially for their learning progress (Sutton-Smith, 2009). Seminal work by Piaget suggests that children undergo cognitive, physical, and social development during play (Piaget, 2013). Thus, toys are critical for pre-schoolers' development in these aspects. Understanding the developmental needs of small children informs discussions and inventions about technology augmented toys for early childhood.

Previous studies indicate that **developmentally inappropriate** technology use can negatively affect pre-schoolers' health, and delay their social, cognitive, and physical development (Brown et al., 2011; Wooldridge & Shapka, 2012; Madigan et al., 2019; Verdine et al., 2019). Technology use has been shown to negatively impact those under 2 years old in health and slow their motor development (Brown et al. 2011; Madigan et al., 2019). One-quarter of children aged around 24, 36, and 60 months, are not developmentally ready for school entry after developmentally inappropriate technology use. Moreover, parent-child interactions are more deficient in parent-child dyads who play with technology embedded toys instead of traditional toys (Wooldridge & Shapka, 2012). These poor parent-child interactions potentially lead to deficiencies in social development in the child. In addition, developmentally inappropriate technology decreases sleep duration among children with mental disabilities including Attention Deficit Hyperactivity Disorder and Autism Spectrum Disorder (Aishworiya et al., 2018). Reduced sleep potentially impacts the children's health (Taheri et al., 2004; Itani et al., 2016; Wong et al., 2021).

Some technology augmented toys can be beneficial (Stapleton et al., 2002; Hinske et al., 2008). Well-designed technology augmented toys can discourage many unbeneficial play behaviours, such as a lack of pretence (make believe) in play as well as isolated play (Hong et al., 2019). Furthermore, some specific designs can boost interactions during play. For example, a technology augmented toy with a natural user interface has been demonstrated to support this viewpoint, as shown in Figure2 (Hu et al., 2016). A natural user interface is described as an invisible user interface that interacts via intuitive actions from users (Wigdor et al., 2011). The toy proposed by Hu and others is a voice interactive doll that can promote richer sensory interactions, behaviour interactions, and emotional interactions among

pre-schoolers (Hu et al., 2016). Another storytelling toy has also demonstrated that it encourages children's imagination, with the most significant results among 6-year-olds (Kara et al., 2013).

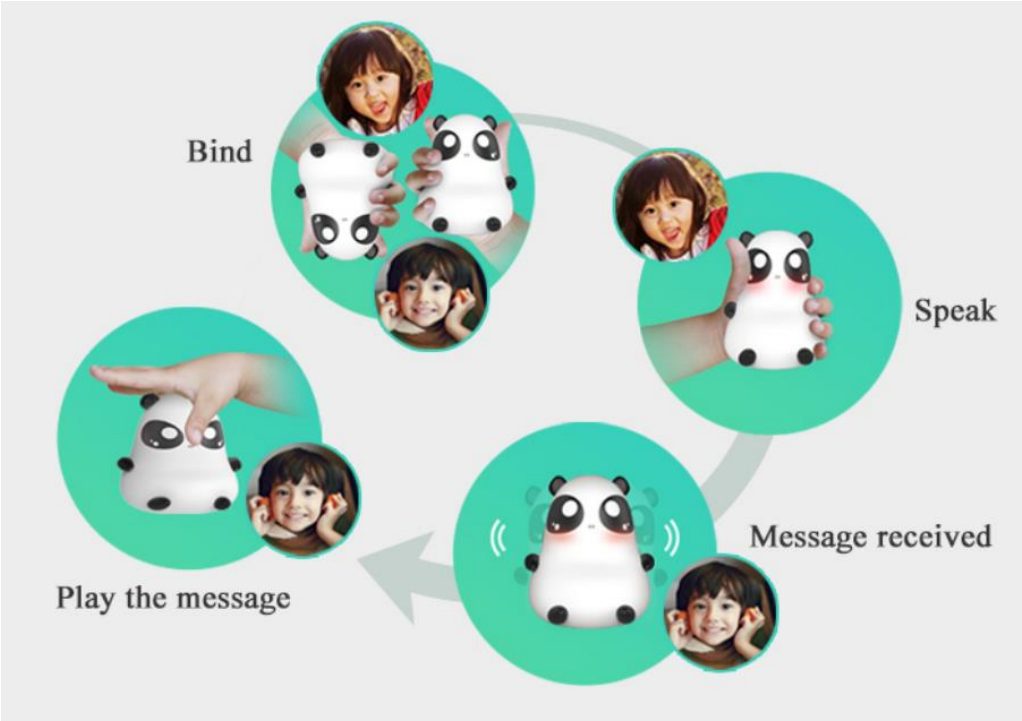

Figure 2: DATU Interactions between the children and the toy with a natural user interface (Hu et al., 2016)

Toy designers need to take extra consideration in design processes and require additional knowledge for creating DATU-centric toys. As demonstrated above, technology itself may not be harmful but the design of technology augmented toys critically determines their effects on children. Toy designers therefore should take serious considerations of relevant knowledge in designing DATU-centric toys. The following are some fields of knowledge necessary in the design processes:

- Cognitive development (children's growth in thinking and reasoning)
- Physical development (children's growth in motor skills)
- Social development (children's growth of ability in interacting with others)
- Safety (minimizing risk of injury and loss)
- Anthropometry (children's body measurements)
- Parents' and child development specialists' viewpoints on toys

Due to the multidisciplinary nature of designing DATU-centric toys, designers need guidelines that handle all these above-mentioned issues. Toy designers, especially novice designers, may have difficulty in taking the right considerations from the ocean of knowledge. Practically, novice toy

designers can miss some considerations as they do not realize their own knowledge gap. Moreover, everchanging technology use can lead to the involvement of new fields of knowledge in toy design. Therefore, toy designers need guidelines to ensure that they are carefully exploring new designs with the right considerations.

1.2.1 Existing guidelines

Numerous studies have tried to utilise some of the relevant knowledge regarding the technology use and/or the child developmental needs (Kelly, 2006; Hinske et al., 2008; Holman et al., 2013; Smith et al., 2013; Hu et al., 2016; Liu, 2018; de Albuquerque & Kelner, 2019; Kara & Cagiltay, 2020). For instance, influential research has clearly defined and matched types of play and toys with respect to different age groups (Smith et al., 2013). These findings are widely adopted in the toy industry but are mostly bounded to traditional toys. The knowledge about children's behaviours may be adoptable, however, the characteristics of traditional toys may not be easily applicable to technology augmented toys.

A guideline founded on DATU principles to assist designers and toy developers in the design and implementation of technology augmented toy environments has been suggested by Hinske et al. (2008). However, this guideline suggested by Hinske et al mainly focuses on how to construct a virtual environment. It is difficult to apply such a guideline for designs of toys that integrate physical and virtual environments. Interactions in the physical environment are necessary as it is theoretically impossible to satisfy the physical developmental needs by playing with toys that offer purely virtual play environment.

Apart from guidelines, there are a few current sources as guidance for designing DATU toys. These sources include design recommendations and result of analysis on existing products. The upcoming paragraphs list the examples of sources of guidance for designing DATU-centric toys.

Previous design-based studies include recommendations for design along with discussion of their technology augmented toys. One study addresses the possibility of applying knowledge from Colour, Material, and Finish design (CMF design) to toys (Jiang et al., 2018). Their design demonstrates how to induce children-toy interactions by satisfying children's emotional needs. Another study applies a natural user interface to promote interactions among pre-schoolers (Hu et al., 2016). These studies demonstrate the effectiveness of their designs in support of children's development. However, the

recommendations are raised from their specific design without holistically exploring different approaches in creating novel toys.

Analysis of existing toys can be used as a reference for designers. One study categorises existing technology augmented toys and analyses them to propose design recommendations respectively (de Albuquerque & Kelner, 2019). Their study also provides an overview of strengths and weaknesses of the existing products. Nonetheless, the findings are general conceptual recommendations that are bounded by existing designs. Stakeholders' viewpoints such as educators and parents are not focally investigated in their research.

Human-Computer Interaction (HCI) discipline also suggests recommendations for UI design from the point of view of the user. For instance, guidelines for designing interfaces for children have been developed by the Nielsen Norman Group, an influential company in providing consultation for user interface and user experience testing (Liu, 2018). These guidelines examine the behaviours of children during their interaction with computers. Nevertheless, the Nielsen Norman Group's work is mostly focused on Graphic User Interfaces (GUI) that are used in touch screens or computer monitors. The findings may not be fully compatible with the interfaces involved in other types of activities, in which users interact with computers differently.

Although rare, more practical guidelines for the design of technology augmented toys exist (Kara & Cagiltay, 2020). The study suggests a set of product development guidelines based upon their previous design-based study (Kara et al., 2014). Their research is started by building a specific type of toy, a storytelling toy. Teachers and children are then asked to give feedback after using the prototyped toy. The guidelines that are made upon these collected viewpoints are organised to cover content, visual design, and interaction aspects of the storytelling toys. However, their research only focuses on educational storytelling toys and solely considers viewpoints from teachers and children. Guidelines for other types of toys are missing and the existing guidelines also lack input from child development specialists and parents.

1.2.2 Problem Statement

The diverse literature and guidelines for designing technology augmented toys are specific in their individual fields. The abundance of relevant studies does not necessarily mean designing DATU-centric toys for pre-schoolers can be supported in practical way. As each set of guidelines being specific in its own field, they can be used as the supportive material tackling different requirements in

making toys. However, the guidelines which support designers to create DATU toys that are developmentally appropriate and take into consideration viewpoints of parents are not widely available.

Therefore, designers need a set of guidelines in order to create DATU-centric toys. The research gap is defined by the lack of holistic, user-cantered guidelines that covers the implementation of everchanging technology use in childhood. The uncertainty regarding DATU design is clarified by taking considerations from what the stakeholders value. The study thus aimed to resolve the problem by taking comprehensive considerations raised by the parents and child development specialists and develop a set of guidelines to support novice technology augmented toy designers.

1.3 Purpose of the study

Studies have focused on the perspectives of individual stakeholders rather than giving guidance that takes into consideration each stakeholder's perspective. These existing studies can provide in-depth knowledge in each specific field of research. However, they do not broadly provide information about what challenges designers will encounter in toy design and how to get through these challenges.

Currently, designers of technology augmented toys lack a set of holistic guidelines that aid designing of DATU-centric toys. The set of guidelines should cover the concern raised by the stakeholders. However, most of the existing studies failed to comprehensively address these concerns.

This study aims to develop a set of guidelines to mitigate the multidisciplinary design process of DATU-centric toys. This study takes the designers' perspective in examining the viewpoints of parents and child development specialists. Hence, this study explores solutions for designers' difficulties in the design process for toy interfaces embedded with mixed reality.

1.3.1 Area of study

This session defines and delimits the specific area of research. Some fundamental assumptions were made about child development. Hence, the area of study is bounded by the several constraints including cognitive development, physical development, and social development. This session then further bound the study by defining the design case for technology augmented toys.

In this present research, several assumptions about pre-schoolers' development are made. It is assumed that pre-schoolers should and will undergo the same developmental curve and behavioural patterns studied from their interactions with traditional toys and practices. This research was also built upon the assumption that pre-schoolers are solely influenced by environmental factors such as play environment, parents, and peers.

In this research, perspectives of cognitive development, physical development and social development are taken as constraints. Piaget's theory of cognitive development, stages of development, and development from the cognitive approach are adopted (Piaget, 2013). It defines the default and expected development processes and corresponding behaviour patterns. In the Nurse theory of physical development, knowledge about physical motions for different ages, are referenceable in interface design (Nurse, 2009). The data and assumptions about children's motor interactions at different ages are critical constraints for this present research. For social development, Cowie's study demonstrated how children are supposed to interact with others (Cowie, 2012). The suggested ways and frequency of interactions are also constraints being accounted for in this research.

Defining the design case is more feasible to further focus the research in comparison with adopting theories from the HCI discipline. There are many existing theories and frameworks proposed for HCI and none of them dominate the industry (Carroll, 2003; Marshall & Necker, 2013). It is reasonable for different designers to adhere to diverse theories. Thus, it is not logical to focus this research by adopting any one of them. Nevertheless, it is possible to bound this research by a design case. From the papers mentioned previously, it can be deduced that the trend of toys will be involved with the computer environment and digital technologies. Migram and Kishino (1994) posited that toys in the future will lay on the virtuality continuum shown (Figure 2) below. As bound by the developmental needs mentioned above, a purely virtual environment is not suitable for young children as it is currently counter-intuitive in accomplishing their physical needs. To aid in physical development some extent of the real physical environment must be involved in the interactions between the toys and pre-schoolers. Therefore, one of the research outcomes is a set of DATU-centric guidelines for designing a toy with a mixed reality interface for pre-schoolers. For ease of documentation and understanding, the word "pre-schooler" means child aged 4-5 years old, and it is interchangeably with "young child", "small child", and other similar terms.

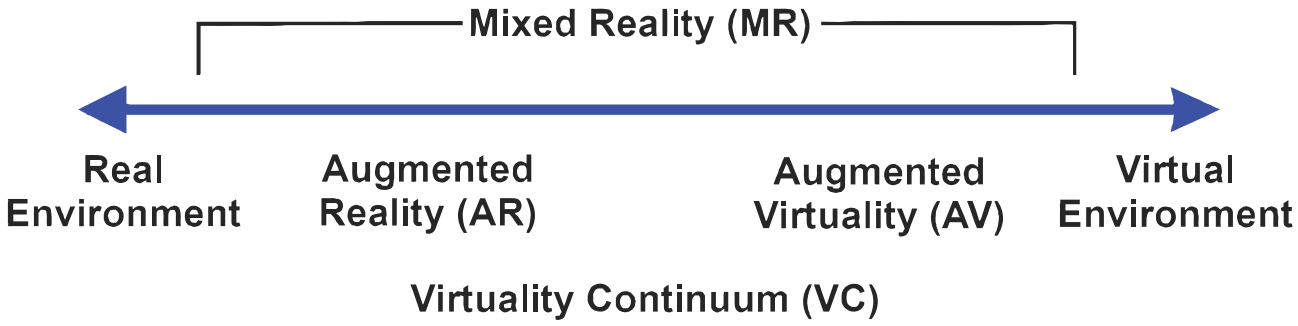

Figure 3: Simplified representation of a "virtuality continuum". (Milgram & Kishino, 1994)

1.4 Contribution

Existing literature confirms that it is possible to integrate technology into traditional toys to enhance play experience while satisfying developmental needs (Hinske et al., 2008). However, the existing designs that positively influence children are mostly focused on the over 5-year-old group while some designs for children younger than 4 years old (toddlers) are proven to be ineffective (Kara et al., 2013). In addition, while studies about toys are widely available, finding referenceable material is difficult because applicable research has been done in various disciplines, with little synthesis of information. Further, although some specific guidelines have been published for designing technology augmented toys for children older than 4 years old (Kara & Cagiltay, 2020), they are either focused on one specific type of play or have neglected viewpoints from important stakeholders such as parents. Therefore, this present research aims to investigate the relevant knowledge, stakeholders' viewpoint and thus resolve difficulties in designing developmentally appropriate technology augmented toys.

One of the research outcomes is a set of design guidelines that can support the design of developmentally appropriate technology augmented toys for pre-schoolers. This research outcome can help childrens' product developers and analysts in this area to design and test novel toys accordingly. Thus, technology augmented toys that satisfy the developmental needs of pre-schoolers can be correctly invented at lower cost than those projects without guidance, due to having a viable model available that includes parents and medical stakeholder recommendations.

The research outcomes will result in contributions to policymakers and academia. The set of guidelines can inspire policymakers to create directives for the toy industry. New policies inspired by this research can ensure more novel toys are made with the necessary care for children and parents. In addition, the practice of design thinking in this research and its result demonstrates the feasibility of

utilizing design thinking in academic research. The findings in this research also show the worthiness of research in toy design.

1.5 Research questions

Incorporating the information demonstrated above, the research questions are as follows.

1. What guidelines are appropriate for novice designers who were creating DATU toys for children aged 4-5 years old?
2. How can these guidelines address the concerns from parents and child development specialists?
3. What are the issues which must be resolved during the design process?

1.6 Research design

The research methodology was founded on the constructivism paradigm which states that each person generates their own set of understandings and views based on their experiences, thus leading to differing perspectives and priorities (Guba & Lincoln, 1994). This theoretical approach allows us to value stakeholders' subjective views of individuals and generate knowledge from them. Therefore, this research is qualitative. As this research was defined to develop knowledge from the designers' perspectives, having designers' participation in the research process was the most intuitive way for to include these viewpoints.

Design-based research framework was adopted to lay the structures of this research. Design-based research is defined as "a series of approaches, with the intent of producing new theories, artefacts, and practices that account for and potentially impact learning and teaching in naturalistic settings" (Barab & Squire, 2004). As indicated by the purpose of this study, the main objective of this research is to create new guidelines that help mitigate the design process of DATU-centric toys from user-centred approach. The design-based research framework, therefore, suited the nature of this research.

This research was conducted in three phases:

1. **Exploring problems:** Explore the difficulties and important issues encountered in the toy design process driven by parents' and child development specialists' needs
2. **Creating solution**: Create and revise a set of guidelines that aid in designing DATU-centric toys

3. **Reflecting on the solution**: Get parents', child development specialists', and novice designers' reflections on the revised set of guidelines

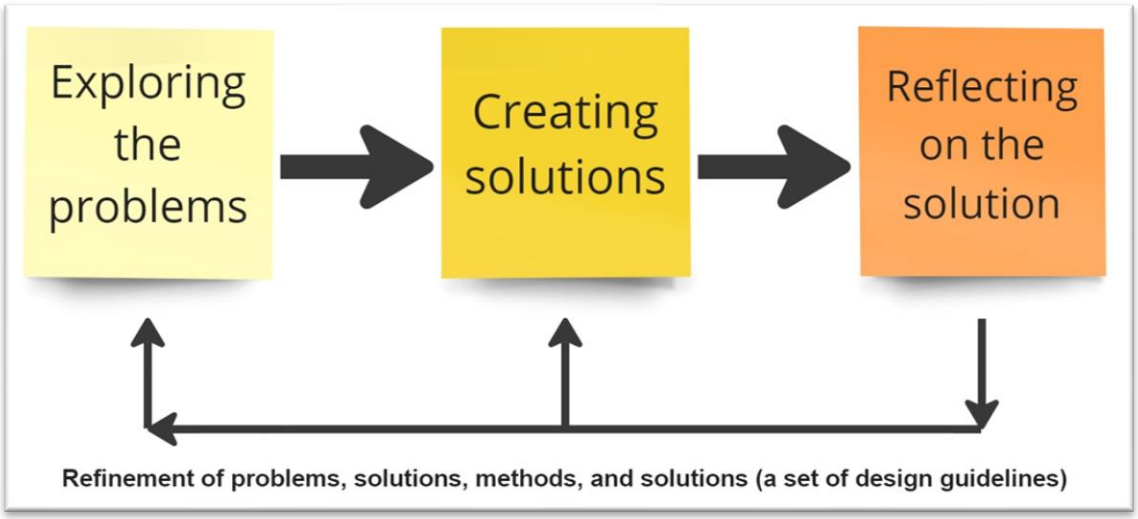

Figure 4: Research framework modified from Design-based research approaches in educational technology research (Reeves, 2006)

The design thinking framework was adopted for conducting the first phase of this research. Design thinking is an approach to developing solutions for complex and uncertain problems (Curedale, 2013; Geissdoerfer et al., 2016). As this problem-solving process originates from studying the stakeholders' needs, it resonates with the research's aim and paradigm. It has five stages, mapping them into the context of this research:

1. **Empathize**: Novice toy designers learn about the parents' and child development specialists' needs
2. **Define**: Synthesize the findings from empathizing stage and thus define the design directions
3. **Ideate**: Brainstorm toy design ideas as preliminary solutions to the defined design directions
4. **Prototype**: Create low-fidelity prototypes for the preliminary solutions
5. **Test**: Test the low-fidelity prototypes with stakeholder

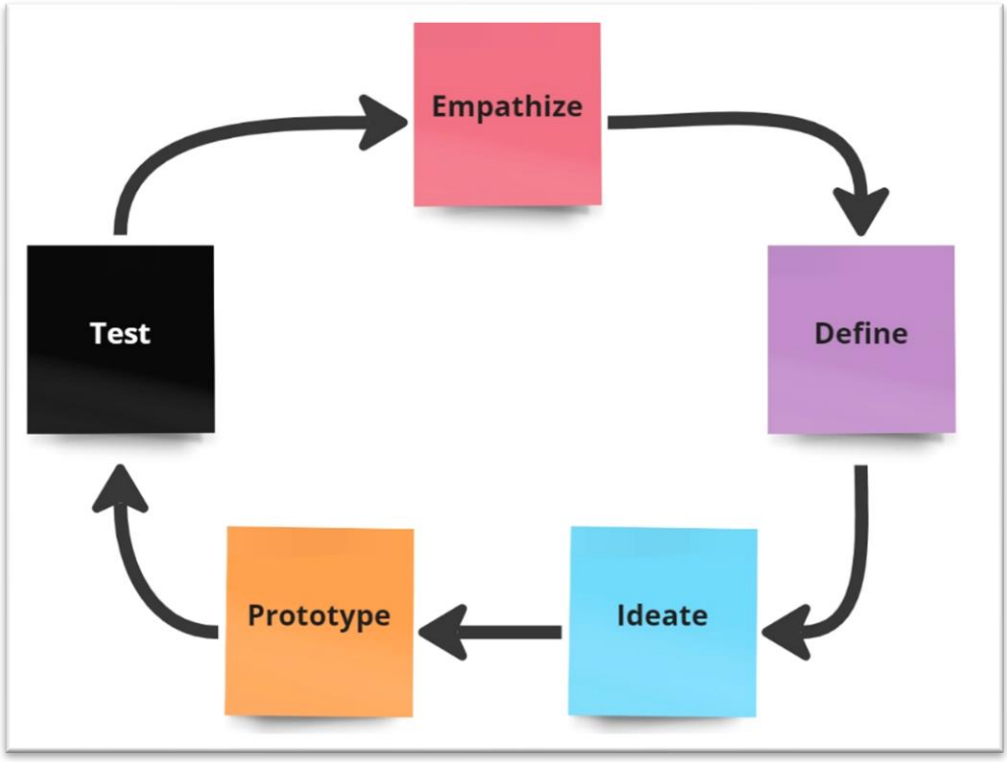

Figure 5: Design thinking framework

Interviews and design workshops were the main data gathering activities used to obtain the qualitative data in this research. Parents and child development specialists were interviewed to gather comments and viewpoints for creating the foundation of the practice project. The practice project was a design project that aim to solve the problems found from parents and specialists. Subsequently, data collected from observations and interviews with novice designers were used to create and revise the solution for mitigating the issues they encountered in their practice project. This study then proposes a set of DATU-centric design guidelines.

1.7 Thesis outline

This chapter has introduced the background, area, research design and contribution of this research. The next chapter of the thesis will highlight the research gap and further bound the area of research with a discussion of relevant studies. The methodological framework that structured the research will be documented in Chapter 3. The practical methods and research activities entailed in the research will then be demonstrated in chapter 4. The data collected in the three research phases will be recorded in Chapter 5. Chapter 6 will then present the finalized guidelines created upon the collected data. Chapter 7 will then discuss the interpretation of the findings and the importance of the research outcomes.

2. LITERATURE REVIEW

2.1 Introduction

This chapter discusses relevant studies to highlight the research gap and delimit this research. Play is important in children's growth (Piaget, 2013). According to Cambridge Dictionary, toy is common object that is used in play. This literature review thus starts from introducing information about toy market. As the market trend is shifting to technology augmented alternatives (Debora et al., 2019; Zhang et al., 2020), designers must seek new solutions –technology augmented toys – to maintain their companies' competitiveness. However, concern arises about the toys' potential negative influence on children, as some existing toys and alternatives have been found to disrupt children's developmental processes (Wooldridge & Shapka, 2012; Carson et al., 2019). This chapter reviews the literature about toys market, pro and cons of technology augmented toys, constraints for designing developmentally appropriate toys, and available design guidelines. The review leads to the research questions, as shown at the end of this chapter.

2.2 Toy market

This section demonstrates the increasing attention on technology augmented toys from industrial and user perspectives. The review on relevant studies focuses on the demand and acceptance for technology use in early childhood. The increasing demand for technology enhanced toys and growing acceptance of these products along with a lack of design guidelines shows that this field of research is worth investigating.

Demand for traditional toys has shifted to alternatives such as tablets and smartphones due to the growing popularity and ubiquity of electronic devices (Debora et al., 2019; Rideout & Robb, 2020; Zhang et al., 2020). Between 2011 and 2020, the percentage of children aged from 0-8 years old who own any mobile devices, has risen from 3% to 48% (Rideout & Robb, 2020). As endorsed by another recent study, technology augmented toys have been attracting customers and would surpass traditional toys in sales numbers in the future (Zhang et al., 2020). In 2017, revenue from traditional toys remained lower than half of the industry's total (Debora et al., 2019). These findings imply that electronic alternatives to traditional toys, such as video game hardware and software, are posing a threat to the sales market.

Technology augmented toys have potential in the market as children's technology use is highly accepted by child-related workers and parents (Brito et al., 2018; Pila et al., 2019). For instance, educators are generally confident in using technology for instructional purposes (Pila et al., 2019), expressing mostly favourable or neutral attitudes towards technology uses. Most of the workers who engage with children aged 0-8 years old, feel positive about using technologies for education (Figure 6); this positivity reflects the interest in technology augmented products for early childhood education. Recent studies have shown that digital technologies have been significantly influencing early childhood education (Preradovic et al., 2016; Gjelaj et al., 2020; Konca & Erden, 2021; Maxwell et al., 2021; Wan Zakaria et al., 2022). Furthermore, parents generally accept technology use during non-educational casual play at home (Brito et al., 2018). The above-mentioned high acceptance of children's technology use reveals parents' and child-related workers' willingness to allow children to play with smartphones and tablets, and indicates an increased market for technology augmented toys.

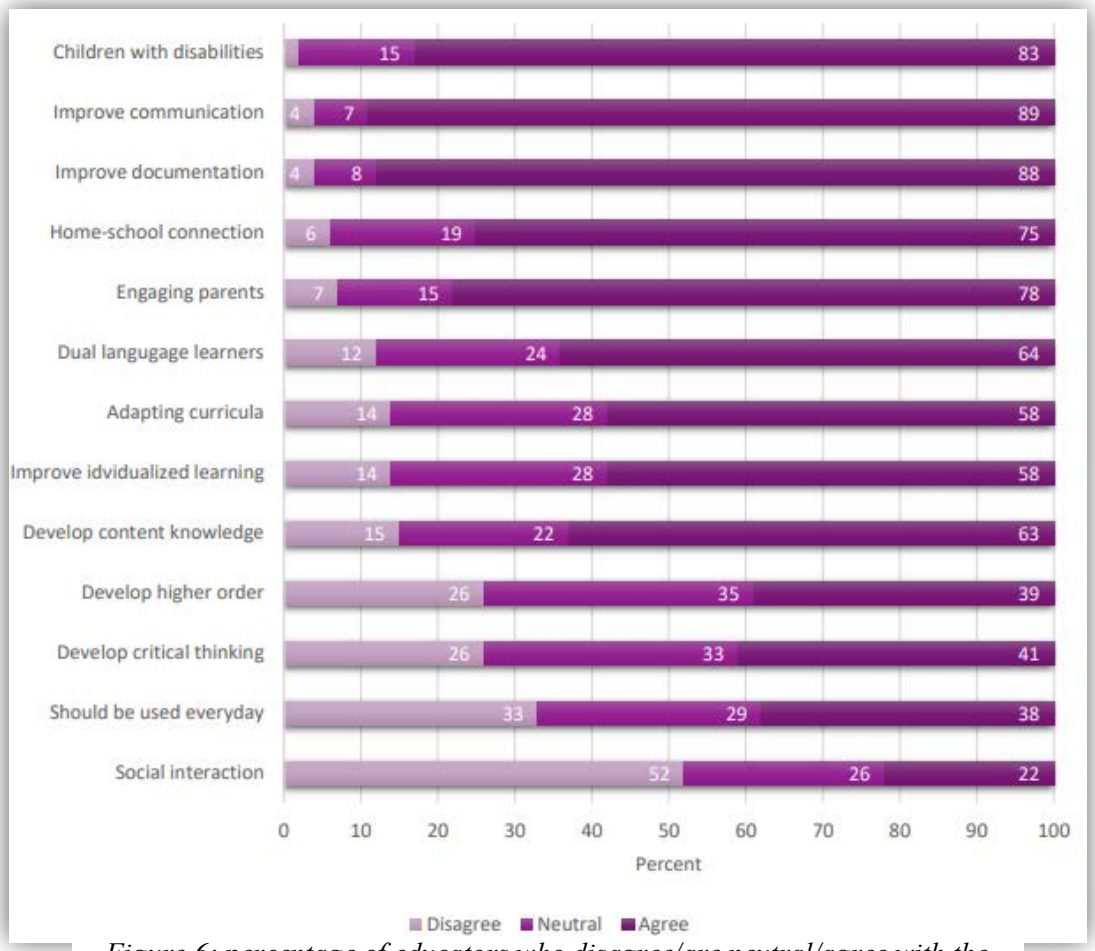

Figure 6: percentage of educators who disagree/are neutral/agree with the value of technology for children's learning and pedagogical practices (Pila et al., 2019)

Major players in the toy industry are adapting to this changing environment by inventing novel toys which include technology (Debora et al., 2019; LEGO Group, 2019). For instance, the LEGO Group has launched a traditional block-building toy embedded with an Augmented Reality interface (LEGO Group, 2019). An Augmented Reality interface is a type of mixed reality interface. Mixed reality can be defined as a communication environment that consists of real physical objects combined with virtual objects generated by computers (Milgram & Kishino, 1994). In the spectrum of mixed reality, the augmented reality interface leans towards the side that has the physical objects dominate the communication environment while having virtual objects as support (Milgram & Kishino, 1994). As an example of this capability, children can use their smartphones or tablets to interact with the virtual objects inside the LEGO toy (LEGO Group, 2019). Correspondingly, they need to toggle mechanical components in the real world to continue the play. To conclude, some major toy manufacturers such as The Lego Group and Hasbro are creating technology augmented toys to maintain their competitiveness ("Hasbro And DMG Entertainment", 2017; LEGO Group, 2019).

2.3 Pros and cons of technology augmented toys

This section documents relevant studies on how technology augmented toys can influence children in aspects such as child development and health. The review begins with a discussion on the importance of play and highlights the potential of toys as the tools being used in play. Later in the section the discussion turns to an examination of some pros and cons in relation to technology augmented toys.

Toys are important in child development (Pellegrini & Jones, 1994). Playing with toys encourages children to explore the range of possibilities of behaviour (Butterworth, 2014). Play is a necessary learning process for children (Piaget, 2013). However, developmentally inappropriate technology use can disrupt this process (Brown et al., 2011; Wooldridge & Shapka, 2012; Madigan et al., 2019; Verdine et al., 2019). Therefore, to support healthy children's development, some constraints for designing developmentally appropriate toys should be addressed during the design process, as demonstrated in a recent study of designing technology augmented companion toys for pre-schoolers (Wang et al., 2021). Thus, this section reviews constraints suggested by the perspectives of paediatricians and parents.

Play is essential for children, especially for their learning progress (Sutton-Smith, 2009). Figure 7 describes the Bronfenbrenner model (Bronfenbrenner & Morris, 2007), and illustrates the many environmental factors influencing children, each listed as a separate circle or level (Gabbard & Krebs,

2012). The microsystem level is the immediate layer of children's interactions with the surrounding physical environment. The mesosystem includes linkages between home and other external systems such as schools, playgroups, and community centres. The exosystem contains two or more linked systems that may affect the child even if they are not part of those systems and the macrosystem holds the child's cultural values and patterns. Of these layers, elements in the microsystems layer being closest to the child causes the greatest, fastest, and earliest influence on children's, cognitive, physical, and social development (Wachs, 1985; Piaget, 2013).

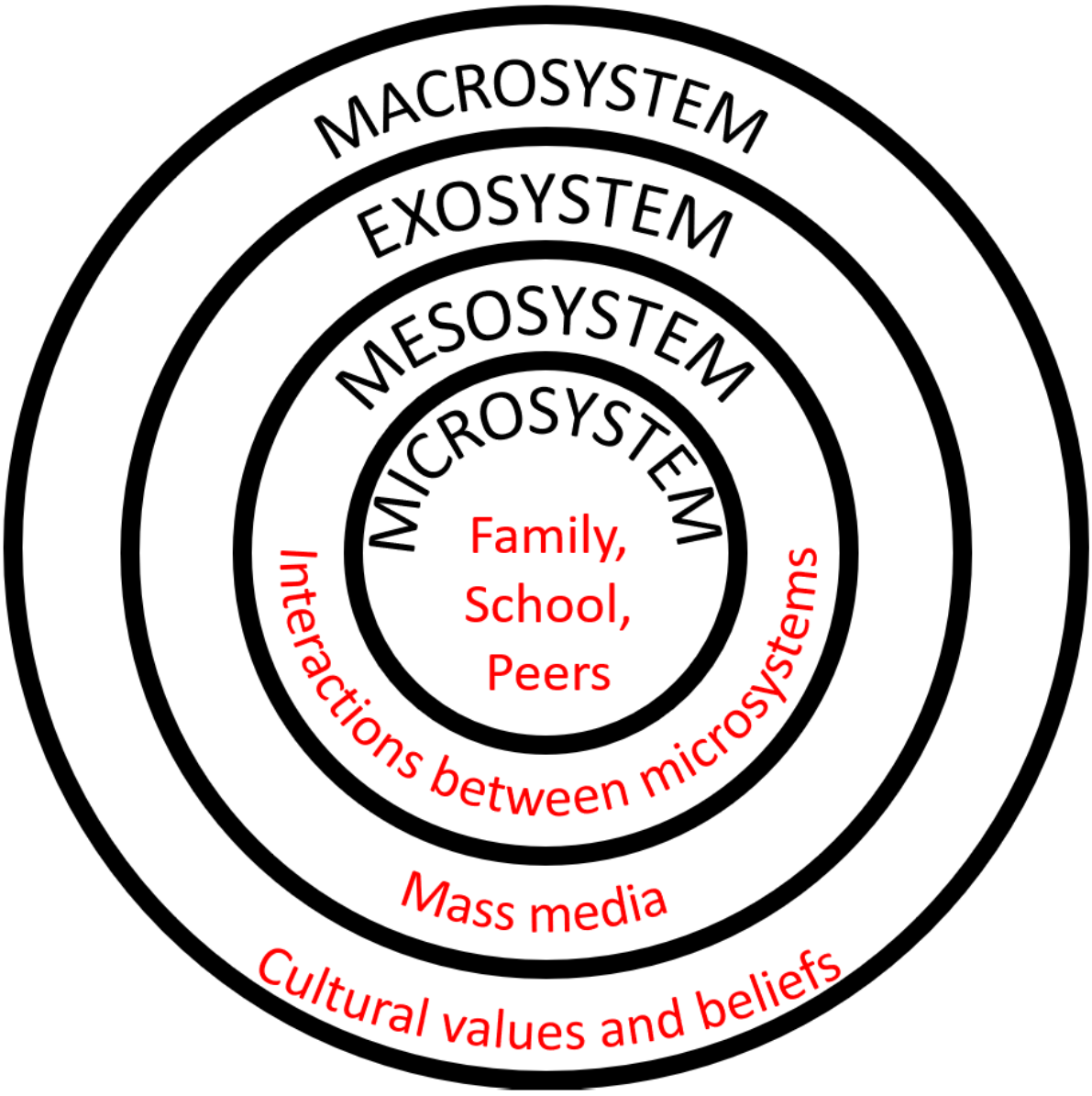

Figure 7: Bronfenbrenner Model with examples of the elements in different layers

Developmentally inappropriate technology use can negatively influence children's growth (Preradovic et al., 2016). Children's needs in the growth of social, cognitive, and physical skills can be used as the bedrock for further understanding the pros and cons of technology use.

Cognitive development is the foundation of understanding children's developmental needs (Piaget, 2013; Wang et al., 2021). For instance, motor development can be analysed and studied from the cognitive angle (Piaget, 2013). Therefore, it suggests that children need interactions with objects via motions such as grasping, throwing and stepping, to gain knowledge (Piaget, 2013). Patterns of behaviour and motivations have been studied and systematically categorised by defining stages of cognitive development (Piaget, 2013). These findings demonstrate what children would do and should do naturally. Therefore, the findings suggest a limit to the interactions associated with toys, with respect to different stages of cognitive development.

Physical development is another crucial consideration as it is related to children's bodily health (Papalia et al., 2009). Practical ideas of children's activities are suggested by connecting professional experience and knowledge derived from the cognitive development (Nurse, 2009). For instance, block-building games as derived from Piaget's work, are recommended for toddlers and pre-schoolers to train their motor skills (Nurse, 2009). This extends to each age group which is matched to its own list of ideal activities, with the focus on physical development. Therefore, designs of augmented toys are bounded to these activities to ensure that specific motions or activities are induced in the corresponding stages of children's development (Nurse, 2009; Wang et al., 2021).

Social development is an essential consideration of children's developmental needs, as social play encourages children to develop thinking, language, and correct ways to deal with emotions (Cowie, 2012). As children can recognise themselves and others after 2 years of age, they therefore become more interested in cooperative activities between the ages of 2 and 4 (Cowie, 2012). Basic cooperative play with one or two friends starts to occur among pre-schoolers. Toys, whether they are novel or not, should be able to support children in these activities (Tonetto et al., 2020). Parent-child interaction is also important in children's social development as they are close playmates of their children (Roggman et al., 2013).

Many studies have critiqued children's technology use and are based on perspectives of social, cognitive, and physical development (Brown et al., 2011; Tandon et al., 2012; Wooldridge & Shapka,

2012; Aishworiya et al., 2018; Madigan et al., 2019; Verdine et al., 2019). Most of the technology use studied showed a negative impact on children under 2 years old in terms of their health and slower motor development (Brown et al., 2011; Madigan et al., 2019). The following findings from existing studies focus on the effects of technology augmented toys on children older than 2 years.

Excess screen time adversely influences children in social, cognitive, and physical development perspectives (Tandon et al., 2012; Madigan et al., 2019). Screen time is described as the time allocated for the use of devices associated with screen displays, such as televisions, computers, tablets, and phones (Tremblay et al., 2017). Frequent and/or long-lasting screen time has been shown to have negative developmental results on small children. For example, Madigan et al. (2019) reports that one-quarter of pre-schoolers were not developmentally ready for school entry after adopting weekly mean screen time of 5-13 hours.

Overuse of screen time can shorten sleep duration for children with mental disabilities including Attention Deficit Hyperactivity Disorder and Autism Spectrum Disorder (Aishworiya et al., 2018). For every additional nine minutes of screen time per day, children's sleep duration has been shown to decrease by one minute. This reduced sleep potentially impacts children's health (Taheri et al., 2004; Itani et al., 2016; Wong et al., 2021).

Lack of geometric knowledge is one of the developmental delays that can be caused by technology use (Verdine et al., 2019). Geometric knowledge is referred to as the understanding of objects' shapes and spatial locations (Verdine et al., 2019). Tablets and mobile phones are less effective than traditional tangible toys in the early development of this knowledge (Verdine et al., 2019). This effect is caused by worsened parent-child interaction during play with non-traditional toys, as reduced interaction leads to restricted usage of spatial language (Verdine et al., 2019). Thus, technology use can delay children's readiness for school entry.

Parent-child interaction is one of the foci for critiquing augmented toys, as poor interaction can cause developmental delay (Wooldridge & Shapka, 2012; Roggman et al., 2013; Carson et al., 2019). Specifically, use of technology augmented toys can diminish the quality of parent-child interactions (Wooldridge & Shapka, 2012; Carson et al., 2019). In one study researchers created a tool called Parenting Interactions with Children: Checklist of Observations Linked to Outcomes (PICCOLO) (Roggman et al., 2013), to compare data collected from parent-children dyads who played with the technology augmented toys and dyads who played with the traditional counterparts. The findings

exposed significantly lower performance in responsiveness from children and teaching effectiveness from mothers, when the children played with the augmented toys.

The above-mentioned studies have demonstrated how technology augmented alternatives can be harmful to children. However, their conclusions are generally based upon existing products that offer minimal social and physical interactions (Wooldridge & Shapka, 2012; Roggman et al., 2013; Aishworiya et al., 2018; Madigan et al., 2019). In contrast, some technology augmented toys such as the above-mentioned LEGO Group's novel one, can provide more of these interactions that can potentially encourage cooperative play and train children's fine-motor skills (LEGO Group, 2019). Therefore, explorations on potential benefits of technology augmented toys have been undertaken in design-based studies (Stapleton et al., 2002; Hinske et al., 2008; Kara et al., 2013; Hu et al., 2016; Hong et al., 2019).

Contrastingly, technology augmented toys can benefit play in some cases (Stapleton et al., 2002; Hinske et al., 2008). Well-designed technology augmented toys discouraged some of the unbeneficial play behaviours seen in traditional toys such as not applying pretence or pretending with the toy, and not engaging in play-like behaviour and non-social behaviours (Hong et al., 2019). To a large extent, the virtual elements in these novel designs link the toys to real-world situations enhancing pretend play opportunities (Hong et al., 2019). Even with these benefits, cooperative play was found to still be weak, however, future improvements targeting these weaknesses are possible by adding inter-object interactions, letting users customize digital augmentation, and revising design for interactive pretend play (Hong et al., 2019).

Some specific designs enrich interactions during play (Wigdor et al., 2011; Kara et al., 2013; Hu et al., 2016). For instance, a technology augmented toy with a natural user interface has been demonstrated to promote richer sensory interaction, behaviour interaction, and emotional interaction among pre-schoolers, as mentioned in Chapter 1 (Hu et al., 2016). A natural user interface can be described as an invisible interface that communicates via intuitive actions from users (Wigdor et al., 2011). Therefore, applying natural user interfaces has the potential to avoid many of the negative effects of screen time (Wigdor et al., 2011). A technology augmented storytelling toy has been invented to provide richer imagination and boost cooperative play among children, with the most obvious results among 6-year-olds (Kara et al., 2013). This storytelling toy, as shown in figure 8, gives a positive effect on play in certain measurable aspects such as play duration, with noticeable results among children older than 4 years old (Kara et al., 2014).

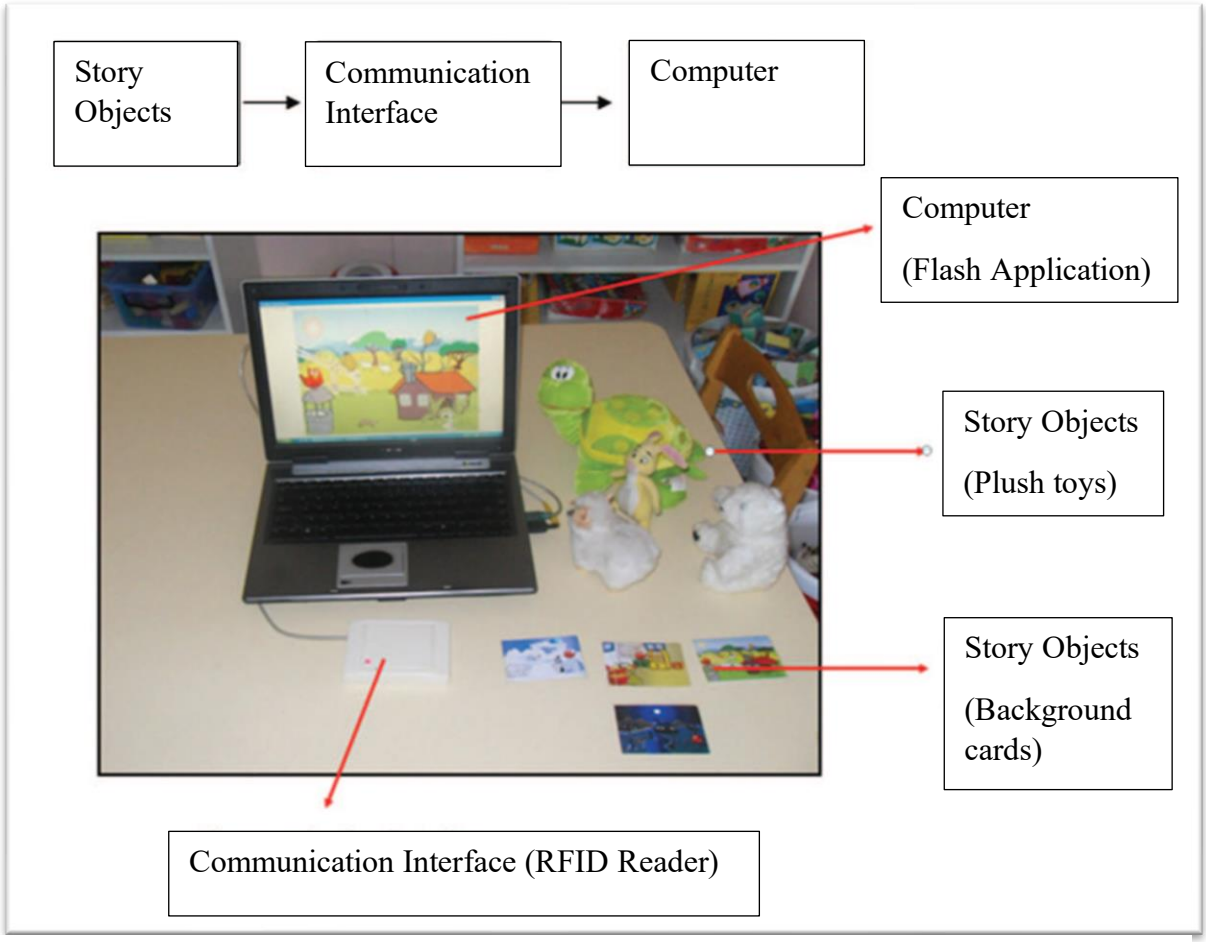

Figure 8: Smart storytelling toy: StoryTech (Kara et al., 2014)

Technology use can enhance the learning experience in educational activities (Birchfield et al., 2006). A platform called SMALLAB has been invented to provide better interactions and learning outcomes for K-12 students (Birchfield et al., 2006), and indicates that well-designed toys can enrich children's learning processes and even human-human interactions. Therefore, technology augmented toys which are considered as the tools that support children during play, may be able to enhance children's learning experiences as well, if they are well-designed and avoid many of the above-mentioned issues.

The appropriateness of a technology augmented toy depends on its design (Rosen & Jaruszewicz, 2008). Examples that took on considerations suggested by child development specialists and educators in design process have shown to positively influence children (Kara & Cagiltay, 2020). A review of these relevant studies further revealed that parent-child interaction can also be a factor in determining the appropriateness (Kara et al., 2014; Hu et al., 2016; Hong et al., 2019). Keeping these implications in mind, the constraints for designing developmentally appropriate toys are examined and demonstrated in next section.

2.4 Constraints for designing developmentally appropriate toys

This section discusses the constraints that should be adopted in designing DATU-centric toys. It covers the viewpoints on technology augmented toys from paediatricians and parents. Safety and usability as implied by anthropometry are also included at the end of this section.

Paediatricians' concerns about technology augmented toys' ability to support children's cognitive, physical, and social development and can be summarised into six points. These factors, as proposed by Daugherty et al. (2014), are briefly described as follows:

1. *"The use must be purposefully integrated to support learning"*
   The technology must be used to support learning or skills building. The technology-based activities must not dominate the learning time of children. Instead, it should be balanced with non-technology-based activities.

2. *"The use must be taking place with others"*
   Derived from the social development requirements, technology use must be at least partly involved with cooperating with others, because collaborative, interactive uses of technology are more preferred during the development of social skills.

3. *"The use must be mobile"*
   Derived from health and motor skills development requirements, technology use must provide motion exercises. The motion-based activities can maintain health by decreasing the severity of obesity and encourage practising motions, which are both critical for children.

4. *"Content and features of media must be age-appropriate"*
   The media or digital environment involved in technology use must match the ages of children. Violent and adult-themed contents must be avoided. Also, the content must be educational, engaging and interactive.

5. *"Device Features"*
   This proposes concerns from safety and the developmental needs perspectives. Devices involved in technology use must be sturdy and easily operated. Also, the shape and interface of the device must support developmental needs. For instance, a tangible interface can support fine-motor skills development.

6. *"Total screen time"*

   Screen time is the time allocated for sedentary and passive technology use, where children focus on the digital screen with minimum motions involved. As sedentary use is not preferred, screen time must be limited, and when screen time is inevitable, it should be balanced with other time slots involving more active physical activities.

Health and developmental needs of children are the most serious concern from parents' perspectives (Chaudron et al., 2018). However, parents' understandings of children's needs vary case by case, as their understandings are influenced by subjective factors such as personal parenting experience and social-cultural factors (Mowder, 2005; Liebling, 2004; Al Kurdi, 2017). Therefore, parents' understanding of children is different from paediatricians' knowledge which is built upon systematic studies.

Although studies about parent's view on children are rare, parent's expectations of traditional toys have been well investigated (Gardner et al., 2012). Most parents expect toys to help children to develop creativity and sociability. The study also suggested that some parents expect toys to induce interactions with family and bring more unstructured play (Gardner et al., 2012). While these expectations were originally found among traditional toys, there is no reason for these ideas to not be compatible with technology augmented toys. Therefore, the parent's expectations of technology augmented toys may include those reflected from traditional toys. More research is needed to substantiate this conjecture.

Parents expect more from technology augmented toys than traditional toys (McReynolds et al., 2017; Brito et al., 2018; Chaudron et al., 2018), particularly the amount of satisfaction that technology augmented toys will afford children including added values (Brito et al., 2018). The added values are mostly educational or developmental oriented. Some parent-friendly features are also preferred, such as parental control and child-play monitoring (Chaudron et al., 2018). Moreover, content filtering is a desirable feature, crucial if the artificial intelligence interacting with children can be accessed and trained by anyone, as strangers may introduce inappropriate content (Chaudron et al., 2018). Also, price is suggested as an extra consideration. The privacy issue also worries parents (McReynolds et al., 2017). These are possible features, needs, and expectations that parents can have for technology augment toys. However, from the scope of this research, the needs of parents as constraints would be subjected to the data collected from participants of this research.

Safety is a necessary constraint for all toys (Taylor et al., 1997; Standards Australia Limited & Standards New Zealand, 2016; ASTM International, 2017). Children are particularly vulnerable and may not be able to foresee a product's failure. Most governmental authorities, like the United States Consumer Product Safety Commission, uses standards to judge the safety of toys (ASTM International, 2017). Most of these standards specify shapes, sizes and features that are prohibited for children below 6 years old (Standards Australia Limited & Standards New Zealand, 2016; ASTM International, 2017). As well-designed toys should be developed to comply with most countries' safety standards, adopting the strictest clauses selected from all safety standards globally would be a wise approach for designers.

Anthropometry, the scientific study of the measurements and proportions of the human body, is another important constraint. Measurements of children's bodies at various ages are recorded (Norris & Wilson, 1995; Pagano et al., 2015). Designing toys with reference to these data, especially for toys with wearable components, can enhance safety and usability. Mismatching dimensions of wearable components with children's head length can result in unexpected movement of the apparatus, which can cause accidents such as choking.

Toy designers should have guidelines in creating DATU-centric toys as it involves multidisciplinary knowledge (Rosen & Jaruszewicz, 2008; Kara & Cagiltay, 2020; Wang et al., 2021). When designing toys, the toy designers should have consideration and certain level of understandings from the above-mentioned fields of constraints. Where experienced designers may have mastered tacit knowledge in toy design, the new technology has created new constraints implied by the viewpoints from parents and paediatricians. Therefore, guidelines suggesting where and how designers should investigate is needed for ensuring appropriateness of technology augmented toys.

2.5 Available design guidelines

Various studies have been conducted in providing guidance for toy design (Kelly, 2006; Hinske et al., 2008; Holman et al., 2013; Smith et al., 2013; Hu et al., 2016; Liu, 2018; de Albuquerque & Kelner, 2019; Kara & Cagiltay, 2020). This section introduces the existing guidelines relevant to the design processes for children's toys.

One study focuses on relations between activities, toy features and children's developmental stages (Smith et al., 2013). The study categorised types of play and features of traditional toys and then

matched them with different stages of development in childhood. First, age groups are systematically defined according to developmental psychology, anatomy and literature primarily about cognitive theory (Piaget, 2013). Behaviours are then sorted for different age groups. Types of play and toys are further defined upon these data (Smith et al., 2013). The toy characteristics are then detailed in domains such as size of parts, shape of parts, level of realism and sensory elements. This study is influential and widely used in the toy industry as the US Consumer Product Safety Commission uses the work as a guideline for making judgements on whether the examined toys match the claimed age group. However, the guideline is mostly focused on traditional toys. Therefore, the data of children's behaviours may be useful, but the characteristic of toys may not be applicable for novel toy.

A set of guidelines focuses on designing games associated with augmented toy environments (Hinske et al., 2008). Designers may be able to use guidelines to construct virtual objects in their novel toys. This is beneficial and timesaving when they aim to design toys which involves play dominated by a virtual environment for example, VR goggles such as *Oculus Rift*. However, this type of guideline is hard to apply during the design of an interface which integrates both physical and virtual environments.

Some researchers construct guidelines by building prototypes (Jiang et al., 2018; Kara et al., 2014; Kara & Cagiltay, 2020). For instance, one design-based study addresses the possibility of applying knowledge from Colour, Material, and Finish design (CMF design) to toys (Jiang et al., 2018). Their design demonstrates how to induce children-toy interactions by satisfying children's emotional needs. In addition, Kara et al.'s works start with the designing of a specific type of toy, a storytelling toy (Kara et al., 2014). By collecting and analysing data from children and teachers, guidelines are made and organised under categories of content, visual design and interaction (Kara & Cagiltay, 2020). For instance, "Design and use of plush toys should be clear and age-appropriate for children" was proposed under the "visual design" category. Kara et al.'s study is useful for designers as it discusses the concept of "virtual environment" which is absent in most traditional toy design guidelines. However, both studies strictly focused on their specified types of toys (Jiang et al., 2018; Kara & Cagiltay, 2020). In certain cases, such as block-building toys and puzzle games, some of these guidelines may not be applicable. Also, the research collects data from teachers and children only, neglecting viewpoints from parents and paediatricians, who are also stakeholders in toys. To fully understand the needs and expectations from all stakeholders, designers cannot solely adopt this guideline; instead, extra work is required.

Knowledge from UI design is widely available and is essential for designing technology augmented toys (Holman et al., 2013; Hu et al., 2016; Liu, 2018). For instance, instead of exploring possibilities via improving traditional toys, researchers have sought proper ways for children to interact with computers. Studies have demonstrated how to create and measure usable interfaces which are potentially beneficial for pre-schoolers. One study focused on applying a Natural User Interface (NUI) among children (Hu et al., 2016). The finding is applicable as a reference for designing novel interfaces for activities based on verbal communication. Furthermore, some researchers introduced a novel approach for developing an Organic User Interface (OUI) which is defined as an interface with non-flat, often flexible displays (Holman et al., 2013). The suggested approach is potentially useful for integrating OUI in wearable toys for pre-schoolers. While OUI will be able to promote a much more natural communication way between toys and pre-schoolers when successfully applied, this knowledge is not directly connecting UI design and paediatrics; extra work is required before applying this knowledge to the toy design process.

Some guidelines do directly connect UI design and children's behaviour. For instance, guidelines for designing interfaces for children were developed by the Nielsen Norman Group (Liu, 2018). Although the study did not focus on mixed reality interface, it examined the new behaviour patterns of children during their interaction with computers, which can aid in designing the technology augmented toys (Liu, 2018). Nevertheless, the Nielsen Norman Group's work was mostly focused on several specific types of interface. As a result, the guidelines do not cover all UI design possibilities. For example, Nielsen's guideline suggested that toddlers will adapt to using virtual buttons which have similar forms to those used by adults. This suggestion neglected the possibility of using physical buttons with designs inspired by traditional toys. Thus, the Nielsen Norman Group's findings are not fully compatible with HCI in other types of activities.

Children's interests and needs on toy were investigated in a participatory design process with children (Kelly, 2006). The study demonstrates a novel child-centred product design method by involving children in the design process. Although this method seems feasible to guide the design direction, it was only tested with those children aged between 7 and 9 years. Thus, it is debatable whether the same method can be replicated for pre-schoolers, as they may not be able to accurately express themselves.

Categorizing and analysing existing toys provides reference of another perspective of users' needs from another perspective. Product analysis helps designers to identify what features are widely used in

the market and what features have not been included. One study mapped more than 290 products into four categories for analysis: Children's Play & Games (CPG), Games & Applications for Fun (GAF), Interactive Social Toys (IST) and Serious Games & Applications (SGA), and exposed some commonalities in those products categorised similarly, and design recommendations were made accordingly (de Albuquerque & Kelner, 2019). Details of these categories are described below.

In the CPG category, the toy's user interface (ToyUI) resembles traditional toy features and related activities. Thus, novelty should be made by enhancing the play quality with a mixed reality experience. In the GAF category, forms of interface are driven by closed-rules activities such as board games. Instead of traditional toy features, products in this category reference traditional games. Therefore, novelty should be made in a similar manner to that of the CPG. In the IST category, ToyUI design is influenced by content-driven play. The products focus on promoting fun by supporting social interaction among participants: for example, AI talking toys and storytelling tools. In the SGA category, interfaces are designed to promote content-driven fun in conjunction with underlying serious purposes. These purposes can be related to education, training or even treatment.

Analysis of the toys in the market may lead to design recommendations that are bounded by existing features. Reverse-engineering existing toy interfaces would cause lack of input from stakeholders such as parents and child development specialists. The possibility of creating new design features that satisfy the stakeholders' needs may be neglected.

A review of the above-mentioned studies showed that existing references and guidelines are individually focused on each specific field. A set of guidelines with the scope of designers originating from child development specialists' and parents' viewpoints is not currently available.

2.6 Chapter summary

Toys can have a huge influence on child development. Children in early childhood develop through play (Piaget, 2013). Toys are important mediums for stimulation and interactions with adults (Roggman et al., 2013; Kara et al., 2014; Hu et al., 2016; Hong et al., 2019). These stimulations and interactions are important elements in supporting child development. Relevant studies have exposed that inappropriate technology use can be detrimental to child development (Wooldridge & Shapka, 2012; Tandon et al., 2012; Aishworiya et al., 2018; Madigan et al. 2019; Verdine et al., 2019). Thus, ensuring the developmentally appropriateness of the design of technology augmented toys is critical.

Rather than focusing on one specific field, toy designers should take multidisciplinary considerations in creating DATU-centric toys (Rosen & Jaruszewicz, 2008; Kara & Cagiltay, 2020; Wang et al., 2021). As suggested by existing literature, there are many fields of constraints that should be adopted in designing DATU-centric toys (Norris & Wilson, 1995; Taylor et al., 1997; Gardner et al., 2012; Daugherty et al., 2014; Pagano et al., 2015; McReynolds et al., 2017; Brito et al., 2018; Chaudron et al., 2018). This implies that designers should know what these fields are and have a certain level of understanding in each field. This is particularly challenging for novice toy designers. Guidelines integrating relevant knowledge required for the design process can aid novice toy designers to build DATU-centric toys.

There are studies utilizing relevant knowledge to provide toy design guidance from specific fields and angles. Some studies focus on the child developmental aspect, while some studies come from technology aspects such as Human-computer interaction and UI design. In considering the needs of stakeholders, some studies come from the approach of analysing existing products. Participatory design and/or creating prototypes for testing with stakeholders are also notifiable approaches adopted by those studies which aim to pioneer new user-centred designs.

Existing guidelines are not holistic and user-centred (Kelly, 2006; Hinske et al., 2008; Holman et al., 2013; Smith et al., 2013; Hu et al., 2016; Liu, 2018; de Albuquerque & Kelner, 2019; Kara & Cagiltay, 2020). There are a vast number of studies focusing on specific fields such as child development. These studies can be very useful when designers are assumed to know what and where to find the relevant knowledge, and how to use it for creating new features that satisfy stakeholders' needs. However, study that starts from novice designers' angle in creating guidance for the design process is not recognized. Therefore, this study aims to create guidance by taking novice designers' perspective in the design process of DATU-centric toys that is initiated from the child development specialists' and parents' needs. Based on this aim and the review of literature, this research was conduct with the focus on the following research questions.

3. METHODOLOGY

3.1 Chapter overview

This chapter documents the research philosophy and framework used in this study. It covers the research paradigm and demonstrates why this research used a grounded theory approach. The previous chapter demonstrated that existing literature focused on specific fields of knowledge. Gap was found as a lack of research synthesising knowledge from multiple disciplines simultaneously. The study hence was conducted upon the case for the multidisciplinary design that synthesis the knowledge from various fields that stakeholders find important. Further details of the adopted design-based research framework and related information such as sampling criteria and research ethics are also included. The details of the research methods (i.e. design thinking activities) are presented in the following methods chapter.

3.2 Research paradigm

A research paradigm provides a foundation on which the research is based. A research paradigm is a perspective or set of beliefs that indicates how the researcher interacts with the world and views the creation or understanding of knowledge. As such it provides a lens through which knowledge and research data can be obtained and understood (Guba & Lincoln, 1994) . The chosen conceptual lens defines what is capable of being studied and dictates how the research should be conducted (Kivunja & Kuyini, 2017).

The adopted conceptual paradigm for this research was constructivism. The theory of constructivism suggests each person develops their own sense of reality as they experience life. This indicates that there are multiple realities that can be studied, and that knowledge is constructed differently by each person based on their subjective views (Guba & Lincoln, 1994). Constructivism was adopted as the fundamental conceptual theory for this research as a way of filling the gap in knowledge regarding ways in which designers can easily take into consideration the viewpoints of parents and child development specialists in the design and development of technology augmented toys.

The choice of research paradigm in turn influenced the research methods chosen. Progressing from the foundation on constructivist theory, the research outcomes were derived from qualitative research methods (Mackenzie & Knipe, 2006). Qualitative research is in-depth research that can help generate a deeper understanding of complex problems and thus nurture new unconventional solutions

(Muratovski, 2016, p.48). A key aspect of qualitative research is that it takes an inductive approach where knowledge is generated from a bottom-up exploration of participant thoughts and views regarding a research topic (Creswell, 2014, p.8). As the research is based in the field of design and the existing guidelines are insufficient for realising solutions to the research gap, grounded theory was chosen be the most advisable approach (Leedy & Ormrod, 2015, P.274; Muratovski, 2016, p.98).

3.3 Grounded theory

A grounded theory study aims to develop a theory based on various types of data collected among multiple phases (Leedy & Ormrod, 2015, P.274). A grounded theory study usually targets the process related to the research topic, as seen in a wide range of fields such as sociology, education, and psychology (Leedy & Ormrod, 2015, P.274). Data are analysed to develop a theory that explains the viewpoints expressed by the participant rather than starting from a pre-conceived hypothesis. Due to the varied nature of the viewpoints of multiple stakeholder groups, and the longitudinal nature of the study, grounded theory was chosen as the best approach for coming to understand these perspectives. The study involved multiple data gathering events across an eight month period.

The following research questions were developed based on the review of the existing literature and choice of the conceptual theories of constructivism and of a qualitative grounded theory approach.

3.4 Design-based research framework

The methodology of this research was further structured with a design-based research framework for managing the ongoing data analysis and dynamic research activities. Design-based research is defined as “a series of approaches, with the intent of producing new theories, artefacts, and practices that account for and potentially impact learning and teaching in naturalistic settings” (Barab & Squire, 2004, p. 2). A generic diagram outlining the purposes of different research phases in a design-based research framework is listed in Figure 9 below.

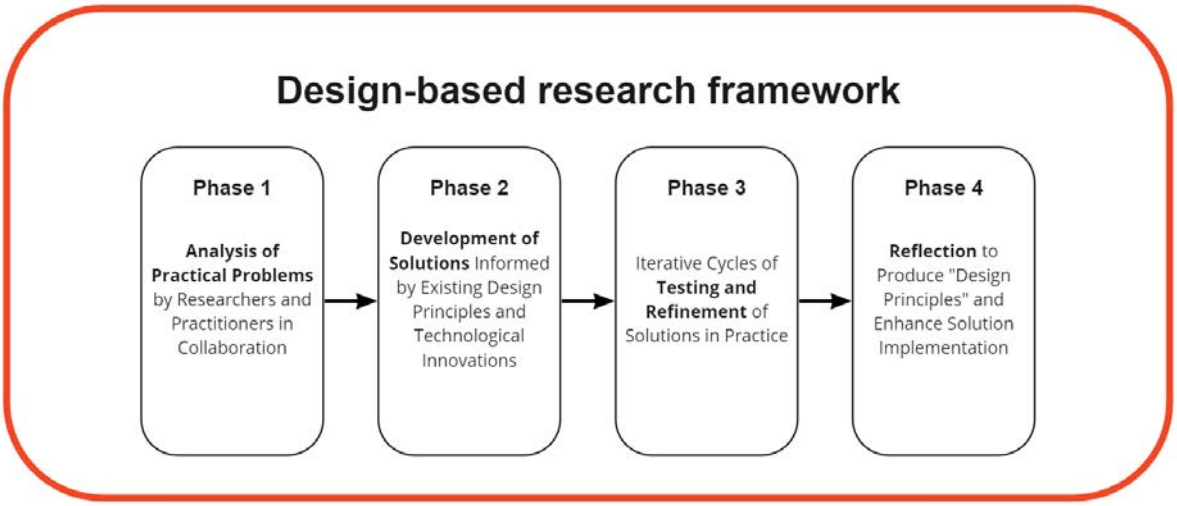

Figure 9: Design-based research approaches in educational technology research (Reeves, 2006)

The Design-based framework matches the aims of the study and the associated research questions. As illustrated above, a design-based framework requires researchers to analyse the practical problem to initiate the development of solutions. This particularly resonated with the third research question on investigating the issues involved in the toy design process. The reflection on the research outcome in the final phase of this framework also aligned with the first and second research questions. Therefore, the design-based research framework was adopted as it aligned with the research questions and the grounded theory approach of this study.

The design-based research framework was modified due to the limited time. The modified design-based research framework only consists of three phases, as shown in Figure 10 below. The phase for implementation and testing of the set of guidelines was removed from the modified framework in this research. However, the means of being iterative in developing the solution was adopted in the second phase of this research. The last phase of this research was similar to the last phase of the design-based research framework, which aimed to get a reflection on the solution. The following diagram illustrates the modified framework adopted in this research.

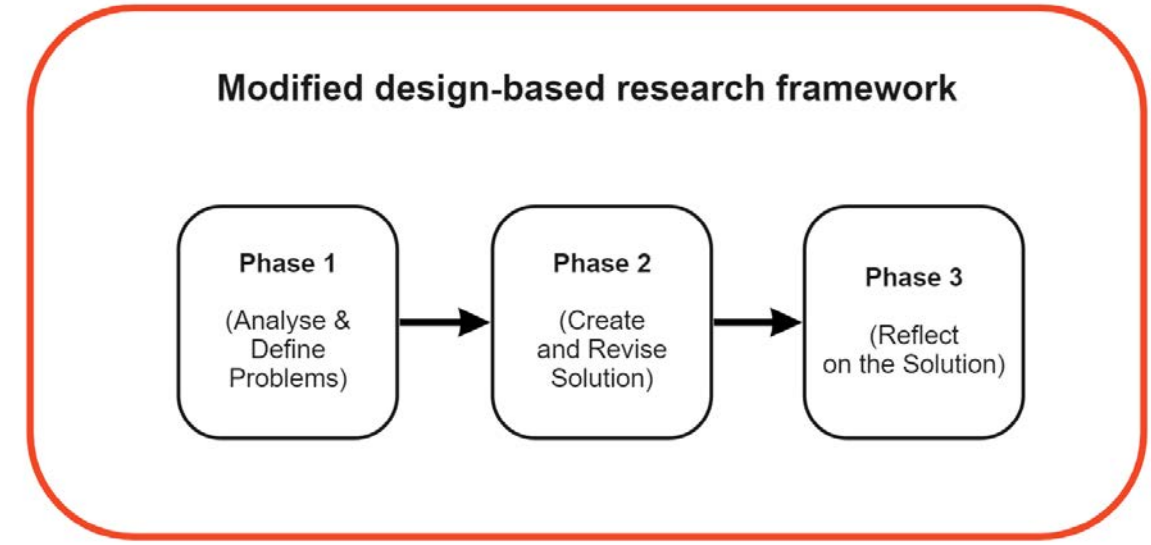

Figure 10: The modified design-based research framework

3.5 Participants and sampling approach

Homogenous purposive sampling was adopted in this research. As this research aimed to study the needs from specific groups of stakeholders, the sampling criteria targeted participants relevant to the research foci (Reed, 1996). Recent qualitative research generating knowledge from stakeholders' needs using homogenous purposive sampling in design related research are found in Zhu et al., (2021).

The sampling criteria used in this study focused on three participant stakeholder groups:

Table 1: Sampling criteria for participants

Groups of Participants	Sampling criteria
Novice Designers	• Having experience in product or interaction design • Feeling comfortable about hosting a discussion • Not having specific toy experience in designing children's products
Child development Specialists	• Having training and experience in the area of early childhood education
Parents	• Having at least one child aged between 4-5 years old in the past five years

Participants were recruited according to the selection criteria above. A total of 10 participants were recruited. The recruitment process will be addressed in section 4.2. The recruits consisted of three parents, three child development specialists and four novice designers. A table disclosing the background of the participants is shown below. As participants' genders and ages were not considered important to the study, such personal details are not included in the table.

Table 2: Background of the participants

Participant's code	Stakeholder group	Background information related to selection criteria
P1	Parents	Has a son aged between 4-10 years old.
P2	Parents	Has a son and a daughter aged between 4-10 years old.
P3	Parents	Has a daughter aged between 4-10 years old.
C1	Child development specialists	An occupation therapist specialising in child development.
C2	Child development specialists	An occupation therapist who owns a business that helps clients who have child development issues.
C3	Child development specialists	A director of a childcare centre.
D1	Novice designers	A lecturer teaching design thinking in a university. Conducted research about design thinking, and co-design with young people in doctoral study.
D2	Novice designers	A staff in a university utilizing design thinking knowledge at work.
D3	Novice designers	A researcher in the engineering field who has knowledge of product development.
D4	Novice designers	An experienced digital product designer utilizing design thinking knowledge at work.

Details of the participant who were selected in each of the stakeholder groups are detailed next.

3.5.1 Novice designers

Participants who satisfied all three sampling criteria for this stakeholder group were selected for this study. Indicated by the word "Novice", the selected designers did not have any experience in designing children's products. This choice was driven by the purpose of investigating the difficulties from designers who are new to the toy industry and technology, but not information technology and/or software development. Previous experience in designing children's products could be seen as a bias for this purpose. However, the selected designers were required to have experience in product development and/or interaction design. Although briefings on the design activities were expected to be provided to the participants, any bias caused made by inadequate skills on conducting the design activities was attempted to be minimised. As product development and interaction design require similar mindsets and skills, the criterion was added for this group of participants. Furthermore, the designers had to be comfortable about hosting discussions with stakeholders because negative feelings against the research activities may lead to insufficient and/or inferior data.

3.5.2 Child development specialists

Participants having experience in the area of early childhood education were selected for this study. In the perspective of child development specialists, this study aimed to investigate the viewpoints that emerged from their knowledge and working experience. The professionals having experience in early childhood education should have sufficient academic qualifications and knowledge to support their daily practice. Therefore, the participants in this group must have experience dealing with pre-school education, such as working experience as an occupational therapist and carer in the childcare centre.

3.5.3 Parents

Participants who satisfied both two sampling criteria were selected for this study. Parents were expected to share their first-hand experiences and viewpoints that had evolved from their time caring for their pre-schoolers. From the context of investigating how they perceive the use of the latest technology in early childhood, the time range for their pre-schoolers to have use of the technology should be within the past 10 years. The 10-year timeframe was reasonably adopted in relevant literature in the past decade, indicating the rising attention on technology use in early childhood (Brown et al., 2011; Tandon et al., 2012; Wooldridge & Shapka, 2012; European Competitiveness and Sustainable Industrial Policy Consortium, 2013; Wartella et al., 2014; Aishworiya et al., 2018; Madigan et al., 2019; Pila et al., 2019; Verdine et al., 2019). However, from the perspective of gathering rich and quality data, the participants with vivid memories about the time accompanying their pre-schoolers would be the most ideal participants for this study. Seeking a balance between

practicality and quality of this research, having at least one child aged between 4-5 years old in the past five years was adopted as one of the criteria.

3.6 Timeline

This research was completed in 10 months. Phase 1 ran for three months for getting novice designers to analyse and define the problems along with the researcher. Phase 2 ran for six months for constructing and revising the outcomes that emerged from Phase 1. Finally, Phase 3 ran for a month for gathering feedback on the revised research outcomes. The following table shows the timelines and general activities of this research. Details of the following activities are listed in the next chapter.

Table 3: Overview of timeline and general activities in this research

Modified design-based research framework phases	Aims	General Activities	Time Period
Phase 1	The researcher and novice designers investigated the difficulties in the DATU-centric toy design process and correspondingly defined the problems	Group discussions, interviews, workshops, and data analysis	August 2021 to October 2021
Phase 2	The researcher and novice designers iteratively created a set of design guidelines upon the discovered problems	Interviews, Email conversations, and data analysis	November 2021 to March 2022
Phase 3	Let all participants reflect on the finalized set of guidelines	Interviews, Email conversations, and data analysis	April 2022 to May 2022

Details of these activities are outlined in the following chapter.

3.7 Limitations and difficulties

There were some methodological limitations in this research. The most significant limitation was time. As design-based research and design thinking frameworks are both iterative processes (Reeves, 2006; Luchs et al., 2016), extra time is required for having iteration in revising solutions. Due to the time constraint bounded by the MPhil study, the maximum number of complete iterations for revising the final outcome was limited to one. However, multiple micro iterations were made to revise research activities according to participants' needs to encourage better outcome within each phase of the

research. Furthermore, the time limit also bounded the number of stakeholder groups. An actual toy design process may also involve other important stakeholders such as children, marketing experts and manufacturers. However, this research only focused on the parents and child development specialists due to the limitation of time and acquired connections. Therefore, the research outcome is bounded by this limitation of scope. However, as the research originated from the DATU concept, having the two groups that were closely related to child development was expected to produce an outcome that fit the scope of this research.

In addition, the lack of homogeneity of the designers' background was a limitation. As each designer had a different background, it was at times hard to confirm whether everyone was "on the same page". Although extra time was given for training and instructions, this variety in training and background in the designer group may affect the results of the study. The set of guidelines produced in this study include some suggestions on how to mitigate this issue.

Finally, arranging meetings with multiple parties at times proved difficult. The participants had different schedules that were unlikely to overlap, and it was hard to arrange face-to-face meetings during the COVID-19 pandemic. Therefore, the research activities were conducted virtually with multiple options for participants to join separately at different times. This may affect the result as the quality of collaboration from participants may be diminished with this virtual meeting approach (Prasetyo et al. , 2022). However, in consideration of practicality and health, this trade-off was justifiable.

3.8 Research ethics

Research ethics is important as this research involved humans. According to the Australian National Statement on Ethical Conduct in Human Research, some conversations may be sensitive to participants as they are related to parenting behaviours. The researcher mitigated this by informing the participants about the activities before conducting any research activities with them, allowing the participant the option of withdrawing from the study or not answering a particular question.

The researcher kept the participants well-informed by providing information sheets and consent forms. Information sheets were provided for apprising all participants of the aims, duration and methods involved in the research activities. Signed consent forms were collected from the participants to ensure that all participants were well informed and agreed to voluntarily participate in the research

activities. This research was approved by the Human Research Ethics Committee at James Cook University with the approval number H8398.

3.9 Chapter summary

The methodology of this constructivist study was framed within the adaptation of a qualitative design-based research framework. The framework mitigated the limitations and difficulties in this research which had as its aim to discover the joint experiences and beliefs of three very different stakeholder groups. Under the adapted research framework, the study was structured into three phases. The first phase aimed to explore the problems for this research, as specified in the first research question: "What are the issues which must be resolved during the design process?" From the scope of aiding novice designers in designing developmentally appropriate toys, the design thinking process and its activities were adopted to facilitate a small design project with the aim of creating conceptual designs. Details of this design activity are detailed in chapter 4. The second phase aimed to create and revise solutions for the explored problems. The final phase aimed to get a reflection on the solution. The reflection was summarised from the final comments on the set of guidelines, collected from all participants. Purposive sampling was adopted to recruit four novice designers, three parents and three child development specialists. As dictated by the constructivism research paradigm, this research aimed to develop knowledge from specific viewpoints, so specific sampling criteria were required for getting the right participants in these three different groups of stakeholders. The sampling size was contained in a manageable scale to mitigate this complex study.

This chapter has outlined the methodological and conceptual frameworks that the study was based upon. The next chapter outlines the methods used in the three phases of the project. A rationale for the choice of each activity in the research design is also given.

4. METHODS

4.1 Chapter overview

This chapter documents the research methods and activities used in this research. This chapter starts with the practical methods of recruitment and data documentation. Then it covers the methods used in each phase. In Phase 1, activities from design thinking literature were adopted, as a toy design project was conducted under the design thinking framework. In Phases 2 and 3, thematic analysis was adopted to analyse the collected qualitative data. Member-checking was adopted across these phases for confirming the accuracy of the data.

4.2 Recruitment

The recruitment was done by distributing flyers on online social media platforms (LinkedIn and Facebook) and sending emails to specialists who have publicly visible contact information. The advertisement via social media was mainly focused on groups that were about parenting, design and paediatrics issues. The recruitment materials clearly stated the background of the research team, the purpose and required tasks of this research, and the selection criteria for participants. Information sheets were provided detailing the research project. This document also further stated that the participation is completely voluntary, and participants can withdraw their participation and/or data at any time during the project without any explanation. The recruited participants were asked to confirm if they were available for this study via consent forms. The information sheets and consent forms can be seen in Appendices. The participants and sampling details were listed in Chapter 3.

There were two potential risks expected from the recruitment and data collection process. The participants may experience anxiety or feel uncomfortable about participating in group sections discussing their parenting techniques regarding allowing their child to use electronic devices. To resolve that, the research activities were conducted in a casual manner. The participants were asked to have positive, constructive dialogue and avoid criticism of each other's ideas during focus group discussions. Participants were told that their responses would be anonymised and confidential, and that the organisers would provide a link to counselling services through Lifeline for anyone in need. In addition, participants could have worried about health issues due to COVID-19 infection. This concern was resolved by hosting contactless online meetings.

4.3 Audio recording and transcription

All research activities involving participants were audio recorded and transcribed with approval from James Cook University Human Research Ethics Committee. As these activities were conducted via an online meeting platform, Zoom, the audio was recorded with an internal function from Zoom. The records were then manually transcribed with NVivo. Although the clarity of the records depended on the quality of each participant's microphone, the conversations were generally understandable. Member-checking was adopted for confirming the findings from the analysis of the records because sending the whole transcripts to the participants may not result in a quality confirmation.

4.4 Methods in Phase 1

Derived from the design-based framework, this research was structured into three phases. The first phase was focused on exploring the problems associated with designing technology augmented toys for small children. As identified in Chapter 3, the knowledge generated in this study came from three groups of stakeholders – novice toy designers, parents, and child development specialists. Mapping this research into the adopted framework, the novice designers were recognised as practitioners in the context of creating a set of design guidelines as the solution. Therefore, the researchers and designers were expected to explore the difficulties and important issues encountered in the toy design process in the first phase. The most straightforward approach was to allow the designers to experience the toy design process first-hand and to note any difficulties they experienced. The Design Thinking framework was then integrated into the design-based research framework to facilitate the toy design process (Figure 11).

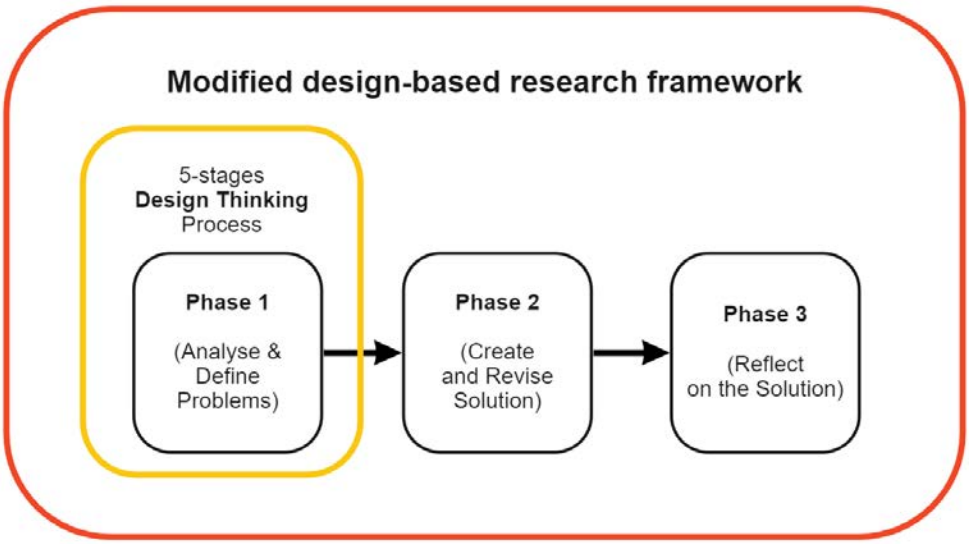

Figure 11: Integrating Design Thinking process in Design-based research framework

Design thinking is a human-centred approach to developing solutions for complex and uncertain problems (Curedale, 2013; Geissdoerfer et al., 2016). Luch et al. (2016, p. xxi) define Design Thinking as a way of "approaching problems and their solutions as a designer would". Therefore, it was a suitable option for investigating difficulties in a simulated set-up of real toy design practice. Furthermore, the toy design process involves multiple parties. Therefore, the Design Thinking framework and its tools were expected to offer sufficient and effective support to this complex problem. Getting to the practical details, Design Thinking is a process generally involving five stages: Empathising, Defining, Ideating, Prototyping and Testing (Gallagher & Thordarson, 2020). The designers and researchers participated in these five stages in the first phase of the research. The data was then obtained from observation of the designers' interventions in these stages, artefacts from the design activities, and the designers' feedback on the process. Preparation materials for these activities including the group discussion guide, interview question guide, and workshop activity outline are documented in the Appendices. The details of these design activities are summarised as follows:

Table 4: Design activities in Design Thinking framework

Stages	Design Activities	Aims	Date & Duration
Empathising	Group discussion: Designers and the researcher ask questions and discuss with the parents and child development specialists	Stimulate thinking by getting participants to share their viewpoints among the group	August 2021 (60 minutes)
	Individual Interviews: Researcher interviews the parents and child development specialists	Investigate deeply into each stakeholder's viewpoint	August 2021 (40-60 minutes)
	Workshop A: Designers and the researcher converge the discovered viewpoints from parents and child development specialists	Converging diverse viewpoints Empathise with the stakeholders	September 2021 (140 minutes)
Defining & Ideating	Workshop B: Designers and the researcher work together in defining design directions and brainstorming ideas	Define design directions Create preliminary solutions	September 2021 (105 minutes)
	Individual evaluation (offline): Designers and the researcher individually evaluate and comment on the ideas outside of the workshops	Evaluate the preliminary solutions	September 2021 (N/A)
Prototyping and Testing	Workshop C: Designers and the researcher select two ideas to create prototypes and present the ideas to a child development specialist	Create and test prototypes	October 2021 (135 minutes)

4.4.1 Method used across all phases: Dot Voting

During the design activities in Phase 1, the team was expected to make decisions on selecting the most promising design outcomes. As resources like time were limited, decisions had to be made for grasping the most promising ideas for continuing development in the next stages. Therefore, dot voting was adopted as it is the most straightforward and time-efficient way that can leverage the strengths of team members with diverse backgrounds (Curedale, 2013). The dot voting technique has been well used in design studies for getting collective consensus in group settings, proving its practicality (Katterfeldt et al., 2012; Zhu et al., 2021). It is democratic and thus makes participants feel safe to express their ideas. Transferring this technique to the online whiteboard platform used in this study, Miro, the participants were asked to place dots or any form of recognisable markers on the ideas in the virtual space. Depending on the contexts of the design activities, the host selected one or two research outcomes with the most dots to carry on to the next design activities.

4.4.2 Method used across all phases: Member-checking

Member-checking was adopted to ensure the accuracy of the collected data. The member-checking was conducted when there were findings from data analysis. For example, in Phase 1: Empathising stage, the parents' and child development specialists' conversations were transcribed. The findings created from the thematic analysis of these transcripts were sent to the participants via emails. In these emails, the researcher asked the participants to confirm the findings and let participants suggest amendments if the findings are not accurate. As most of the data collected in this study are from conversations, all the member-checking activities were conducted in a similar way to ensure the research's credibility, one of the dimensions of rigour in qualitative research.

4.4.3 Methods in Phase 1: Empathising stage

In the Empathising stage, the aim was to find and understand the problem from the stakeholders' perspectives (Gallagher & Thordarson, 2020). Therefore, the designers and researchers were expected to seek the parents' and child development specialists' viewpoints on electronic pre-schooler toys. The fundamental element of this stage was to listen to the stakeholders. The research thus then implemented a group discussion followed by individual interviews with each of the stakeholders.

Group discussion followed by individual interviews can increase the accuracy of the stakeholders' viewpoints as people may give different answers in these two different settings (Curedale, 2013). The

1-hour group discussion encouraged all participants to share their thoughts freely in a way similar to brainstorming. This was aimed to get everyone on the same page and induce stakeholders to organise their perspectives before getting interviewed. Each semi-structured interview with stakeholders being interviewed by the researcher lasted for 40-60 minutes. These individual interviews aimed to encourage the participants to talk about their experiences and viewpoints deeply without the potential disruption from dominant participants in a group setting. Member-checking was conducted to ensure that the findings from the stakeholders were credible.

The researchers and the designers were then required to organise the data from the conversations. One activity used was drafting an empathy map for each stakeholder. An empathy map (Figure 12) is a four-segment map describing what a user says, does, thinks and feels. As the empathy maps were drafted together by the whole team, it can ensure that everyone in the design team understands the stakeholders' needs in the right context (Curedale, 2013).

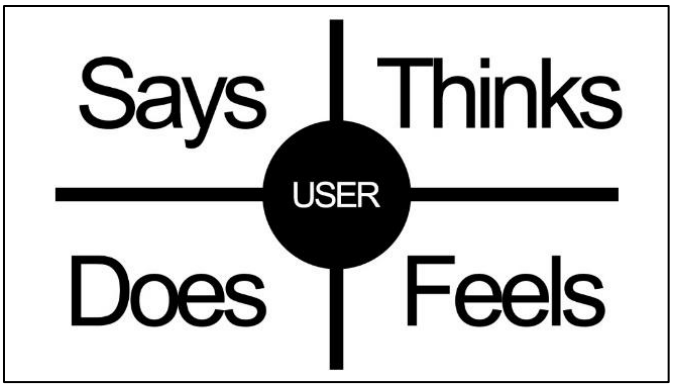

Figure 12: An empathy map

4.4.4 Methods in Phase 1: Defining stage

In the Defining stage, the aim was to clarify the obtained understanding of stakeholders and focus on the problem in a way that encourages meaningful solutions (Gallagher & Thordarson, 2020). Using the artefacts such as the empathy maps from previous stage, the designers and researchers created several problem statements, and these statements were later transformed into actionable questions starting with "How Might We".

Problem statements were aimed to help designers recognise the pattern from their understanding of stakeholders and create a targeted starting point for ideation (Gallagher & Thordarson, 2020). A problem statement consists of three elements: who the user is, what your user needs and the insights or meaning that rise from satisfying the needs. A well-defined problem statement can help designers realise where to put their effort in a project (Curedale, 2013).

Further work was required as the problem statements contained excessive information for ideation. The problem statements had to be refined into a more compact and actionable form (Curedale, 2013). Therefore, the problem statements were translated into questions starting with “How might we”. These How-Might-We (HMW) questions served as an entry for designers to start their exploration of solution space in the Ideating stage (Gallagher & Thordarson, 2020). The use of HMW questions can help get the team ready for the design challenge in the right direction.

4.4.5 Methods in Phase 1: Ideating stage

In the Ideating stage, the aim was to explore possibilities in the solution space. The general workflow of the ideation stage was individual brainstorming followed by group brainstorming. This arrangement was made to enhance the diversity of the ideas. The depth of these ideas can then be elevated by group brainstorm. These idea Group decision-making on selecting which ideas for further development was made by dot voting.

In consideration of time cost, the generated ideas should be converged so the team can focus on the most promising ideas in the prototyping stage. The designers were asked to evaluate each other ideas. To prevent bias, individual evaluation on these ideas was conducted individually by each designer between the meetings. This arrangement was made as finding relevant knowledge for evaluating the ideas required extra time.

4.4.6 Methods in Phase 1: Prototyping and testing stage

In the Prototyping and Testing stage, the aim was to realise the ideas in presentable forms for getting feedback from stakeholders (Gallagher & Thordarson, 2020). Based on the consideration of time cost and purpose of this phase, low-fidelity prototypes were made for testing. Storyboard was adopted as the form of the prototype. As the main purpose of these design activities was to let novice designers experience the toy design process, the design thinking process was stopped after the testing stage. Instead, the designers were asked to share their thoughts on the whole design process in a group discussion setting. The captured data was then carried to the second phase of the research.

Storyboards were made on a virtual whiteboard for testing ideas. Defined by one of the leading companies in user experience, Nielsen Norman Group, “a storyboard communicates a story through

images displayed in a sequence of panels that chronologically maps the story's main events." (Krause, 2018, para. 2). This visualised story was meant to carry the stakeholders from defined problems to expected benefits from the solutions. The visuals can make the ideas easy to understand and memorable for the stakeholders (Krause, 2018). An example of the storyboard derived from the one given by the Nielsen Norman Group is visualised below (Figure 13).

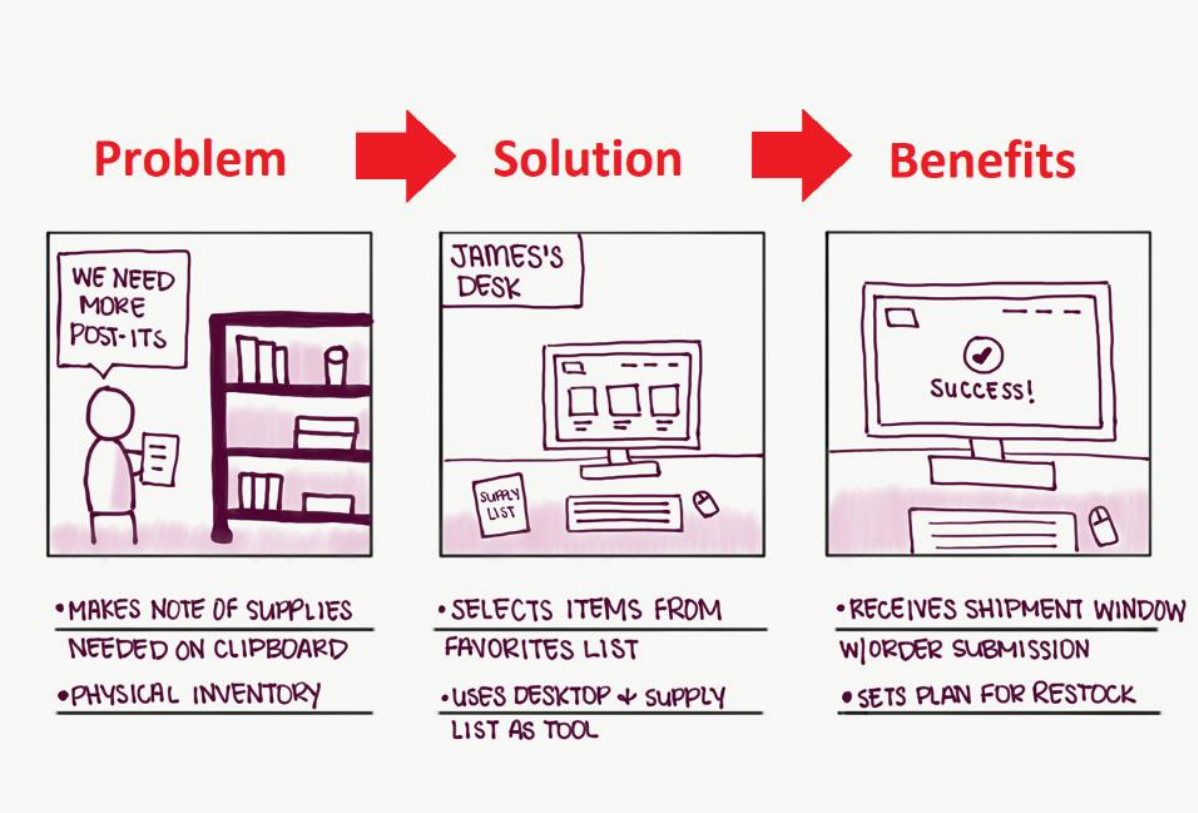

Figure 13: A Storyboard example (Krause, 2018)

4.5 Methods in Phase 2

The second phase aimed to create and revise the solution. The solution in this context was the set of guidelines that aid DATU pre-schooler toy design. Creating the solution required a review of the data. The data were obtained from three parents, three child development specialists and three designers in the form of emails, audio recordings and graphs as design outcomes from the first phase. The data from stakeholders and designers were reviewed by using thematic analysis.

Thematic analysis is a method for investigating and analysing patterns among qualitative data (Clarke & Braun, 2017). Thematic analysis offers high flexibility and provides rich, and detailed data (Nowell et al., 2017). Therefore, it was expected to aid in recognising and organising the complex problems

involved in this research. The data from the first phase was coded into themes, presenting three distinct perspectives from three groups of participants. A set of preliminary guidelines was then made by linking existing literature and knowledge to the problems scoped by the designers. As this set of guidelines was meant to be viewed by designers, it was initially structured into three sections resonating with the design thinking process – Understanding, Defining and Creating. As the design-based research framework is iterative, the set of preliminary guidelines was presented to the designers for feedback. The feedback, as a new set of data, was reviewed with thematic analysis. The findings were used to revise the set of guidelines. As one of the changes, another session was added, documenting how to collaborate with stakeholders. Tackling the varied unstructured data, a flexible thematic analysis approach was adopted from the work of Braun and Clarke (2006). This approach had been adapted and used in research involving the analysis of the artefacts and transcripts obtained from design activities (Zhu et. al, 2021). The adopted thematic analysis consists of four steps: familiarising with the data, generating initial codes, searching for themes and reviewing themes.

It is fundamental to become familiar with the data early in the process of thematic analysis. Immersing the researchers in the data usually involves repeatedly reviewing data, and it is crucial to do it at least once before getting into the next step of thematic analysis (Braun & Clarke, 2006). During this process, initial ideas on the meaning and patterns from the data can be formed. These ideas can help identify initial codes in the next step. Practically, transcription is an effective way to let researchers become familiar with the data (Braun & Clarke, 2006; Zhu et. al, 2021). Therefore, in this research, transcription of verbal data was mostly used as the way to get familiar with the data. Other types of data, such as the design artefacts, were reviewed and generated some notes on initial ideas of potential findings as a result.

Generating initial codes aims to start extracting meanings and/or patterns from the data. Codes are notes that identify interesting features from the dataset with respect to the research questions (Braun & Clarke, 2006). The codes found in this study were based on the participants' viewpoints and the artefacts from the design activities. Coding is initiated by attaching the identified features to the most basic element or segment of the raw data (Braun & Clarke, 2006). In this study, manual coding was made by highlighting segments of data in NVivo. For example, quotes from the transcripts made in the previous step were highlighted with codes identifying the meanings related to the research questions.

Searching for themes aimed to analyse data from a broader level. The broader analysis can be done by sorting and collating relevant codes into potential themes (Braun & Clarke, 2006). Practically, it can be initiated by visualising the codes in a workspace. In this study, the online platform Miro was also used as a virtual workspace for conducting this activity. The codes were visualised as sticky notes in the workspace. Similar notes were then placed into the same theme pile. In this process, each code can be in multiple theme piles and theme piles can be merged into broader piles or broken into subthemes. The map connecting the codes and themes was purposed to visualise how the insights come from the raw data, as presented as findings in later stages of this study.

Refining themes is important as indicated by the iterative nature of the research framework. As the thematic analysis in this study was made with an inductive approach, the reviewing of themes was also data-driven. In previous steps, the codes and themes were generated from small segments from the dataset. However, the found themes and codes may not be true for the whole dataset. The reviewing of themes started by cross-referencing the similar codes that originated from different participants. This process aimed to find the true meaning behind the contrasting codes under the same theme. The bottom-up approach of revising the codes further commenced the revision of subthemes and major themes. Further checking was done to ensure the correlation between the themes and research questions.

4.6 Method in Phase 3

The final phase aimed to get a reflection on the revised solution. The revised set of guidelines was presented to the participants for getting reflection. The presentation covered how we did this research and the major findings created from the past activities. The conversation after the presentation was similar to a semi-structured interview. The participants were asked if they have any difficulties understanding the content in the presentation. The researcher answered and elaborate concepts to eliminate confusion. At the end, the participants were asked to comment on the research outcomes.

From the designers' perspective, the intention of getting reflection was to confirm that the set of guidelines is satisfactory. This can provide more confirmability for the research outcome. From the parents' and specialists' perspectives, the intention was to investigate whether the set of guidelines was addressing their concerns about DATU pre-schooler toys. In consideration of time cost and difficulty of arranging a meeting with every participant, a video presentation along with the actual

documents was given to each participant. This is also acting as a member-checking process and thus assure the credibility of the research outcome.

Another process of thematic analysis same as the one in Phase 2 was used to find patterns and meanings from the conversations. The methods are the same as the goals and types of data in the analysis processes across these phases are identical. Due to limitation of resources such as time and connections, the findings from the analysis were documented as possible future work.

5. RESULTS

5.1 Chapter overview

Data collected in this study were collected from three groups of stakeholders: parents, child development specialists and designers. Phase 1 data were collected from group discussions, interviews, and design workshops. Phase 2 and 3 data were collected from interviews and email conversations. The overview of the data collection activities can be seen in the Table 2, as restated as follows:

Table 3: Overview of timeline and general activities in this research

Modified design-based research framework phases	Aims	General Activities	Time Period
Phase 1	The researcher and novice designers investigated the difficulties in the DATU-centric toy design process and correspondingly defined the problems	Group discussions, interviews, workshops, and data analysis	August 2021 to October 2021
Phase 2	The researcher and novice designers iteratively created a set of design guidelines upon the discovered problems	Interviews, Email conversations, and data analysis	November 2021 to March 2022
Phase 3	Let all participants reflect on the finalized set of guidelines	Interviews, Email conversations, and data analysis	April 2022 to May 2022

First part of this chapter explains three domains of data found in Phase 1: 1) Viewpoints from parents, 2) Viewpoints from specialists and 3) Needs of designers on toy development progress. The context of viewpoints in the first two domains was targeted at the children's play environment and the third domain was targeted at the toy design process. This chapter then explains the explored problem(s) after holistically analysing these three domains of data. The findings in Phase 1 were interpreted into guidelines along with relevant literature. The preliminary guidelines were structured into three parts: Understanding stakeholders, Defining problems, and Creating solutions. The set of preliminary

guidelines can be seen in the Appendices. The aim of the set of preliminary guidelines was to help novice designers to navigate the toy design process. It was presented to designers and the designers were asked to comment on and question the guidelines. The collected feedback is documented in the second part of this chapter as Phase 2 data.

The set of preliminary guidelines was revised according to the findings in Phase 2 data. The revised set of guidelines was then presented to all participants via email and online meetings (interview). The online meetings allowed the participants to familiarise themselves with the guidelines and get their questions answered interactively. The participants were then asked to comment on the revised guidelines. The collected feedback came from one novice designer, one parent and one child development specialist. The aim of collecting the feedback was to confirm that the set of guidelines addressed the stakeholders' needs to an extent. The data are documented in the last part of this chapter.

5.2 Phase 1 data from parents

The parents' data on pre-schooler toys were categorised into seven themes: ***Play activities, Values from play, Toy attributes, Interactions, Screen time, Safety and Imagination.*** Each theme represented a specific angle on what parents expect and concern from the pre-schooler toys. The following table briefly lists the major findings gathered from parents in Phase 1 of this research.

Table 5: Findings of Phase 1 data from parents

Themes	**Parents' viewpoints**
Play activities	Play was recognized as a relieving activity.
	play environment should be balanced between technology use and other activities, yet dynamic to involve different types of play.
	The mechanics of the play should be understandable by pre-schoolers yet interesting enough to encourage various types of play.
	Electronic toys having extra features limited the imagination.
	Cooperative play is preferred.
	Pre-schoolers can have indoor physical exercise as part of the play activities involving toys.
Values from play	Pre-schoolers should gain some benefits from play.
	Educational values from play included human values, history, culture, critical thinking, questioning and analytical thinking.

	Play should provide opportunities to holistically support pre-schooler development.
Toy attributes	Fundamental considerations for choosing toys are physical safety, educational value, sensory stimulation, and reliability.
	Reasonably priced toys were preferred and microtransactions were not preferred.
	Internet safety, user experience, and reliability of electronic toys are questionable.
Interactions	Social interactions were important to pre-schoolers.
	Parents like to enhance their relationships with children via interactions through different roles in play.
	Toy-child interactions should be continuously engaging.
Screen time	The parents recognised that children's screen time had risks and benefits.
	Management was needed for technology use in childhood.
Safety	Physical safety was fundamental.
	Content safety and internet safety were concerns about electronic toys.
Imagination	Children preferred the use of imagination.
	Toys should provide space for imagination.

In *Play activities*, the data described the parents' expectations on what kinds of activities their children should have and what electronic toys brought changes to children's play. However, their data did not necessarily directly relate to toys as the focus was on the nature of play. In *Values from play*, the data reflected what parents wish their children can learn from play. Rather than just solid knowledge, the benefits also include skills and stimulation.

In *Toy attributes*, the result presented parents' requirements or preferences on toys. The requirements were often linked to their expected values from plays involving toys. Each participant may have a slightly different position in the love-hate spectrum on toys, but the generic preferences on toys were discernible. In *Interactions*, the result described the parents' envisioned human-toy and human-human interactions. These desired interactions also led to the parents' roles in play. In *Screen time*, the data were bound to the influences from screen time foreseen by parents and parents' actions on screen time. In *Safety*, the result showed different types of safety concerns on toys suggested by parents.

Imagination was recognised by parents as an important key to both motivating children and bringing benefits to childhood and parent-child relationships as described in this chapter.

5.2.1 Play activities

Parents' data on *Play activities* were summarised into four findings. The parents generally agreed that play can be relieving, and pre-schoolers should have a balanced yet dynamic play environment. The parents' expectation of balanced play also extended to the mechanics of the play. The parents suggested that the play activities should be simple enough for pre-schoolers to understand but not boring. The parents also proposed their insight on indoor physical exercises as play activities.

Fundamentally, parents put their attention on the purposes of play. Parents treated play as a relieving activity, apart from just getting practical values that are addressed in the next session. Play activities were recognised as ways for pre-schoolers to have fun. Some parents said they would like to have relaxing toys for their pre-schoolers. The electronic toys' potential for fulfilling this purpose was further suggested by one of the parents with tablet games as an example to create an immersive digital world for children to escape from the stressful real-world environment. The idea of relieving the children from stressful or even unsafe reality could be seen in the two following statements:

I think sometimes electronic toys can be maybe good for children that don't have safe environments and they can almost escape for a little while. (P3)

I'd be very interested in more electronic toys coming out that has you know could read, so you know could read a story and play music, can do lots of different things like a you know to soothe the child. (P3)

Parents liked to maintain a balanced yet dynamic play environment. The parents agreed that pre-schoolers should have a balance between technology use and other activities. The parents suggested that technology use was not completely banned but was managed. This concept demonstrated a linkage with the need to create a dynamic play environment, which involved different types of play. The acceptance of allowing pre-schoolers technology use indicated that electronic toys had unique values from parents' perspectives, which are documented in the next session.

Further looking into the context of the play, parents suggested that the mechanics of the play should be understandable by pre-schoolers yet interesting enough to encourage various types of play. The

play should not be as boring as the repetitive play that was adopted for babies. However, the complexity of the play should be reasonable for pre-schoolers who cannot understand complicated game mechanics. Furthermore, a preferable play would be enabling pre-schoolers autonomy by letting pre-schoolers initial play and develop on their own. The parents' recognition of the importance of building autonomy can be captured from one of the statements:

He develops his character by interacting with stuff that (is) beyond your control is just… it's just part of his development. (P1)

The restriction on play mechanics brought by electronic toys was specifically suggested. The parents suggested that electronic toys having extra features limited the imagination. As the play was driven by the predefined toy features (personality and a voice), the lack of autonomy disengaged pre-schoolers from the play. This concept was found in the following statement:

… a lot of toys already come with a personality and a voice, and so the child can't put its own imagination to it. (P3)

Seemingly contradictory to the promotion of autonomy, the parents suggested their preference for cooperative play. Rather than just solitary play, parents wished their pre-schoolers could play with others, preferably with cooperation towards a common goal. This paradox between autonomy and cooperation can be explained by the need to introduce a dynamic play environment to pre-schoolers. This concept was summed up by the following statement:

I will still try to kind of give a diversity of different things, and so in here the experience of different stuff … (P1)

Lastly, parents shared their insight that pre-schoolers can have indoor physical exercise as part of the play activities involving toys. Parents suspected that toys are for indoor activities only and they valued physical exercise as one of the important activities for pre-schoolers to have. The suggestion for using electronic toys to encourage pre-schoolers to have indoor physical exercise was also raised by one of the parents. This insight can be seen from the following quote:

Imagine if we had all these electronic toys that were promoting physical exercise within a small, confined environment. (P1)

5.2.2 Values from play

The parents' data on *Values from play* were summarised into three findings. Fundamentally, the parents wished their pre-schoolers to gain certain benefits from play. Although a parent perceived that the values of educational toys were being exaggerated, most parents positively introduced a vast range

of educational values. They also further shared how play activities provided opportunities that can support the development of skills.

All parent participants wished their pre-schoolers to gain some benefits from play. This expectation was explicitly addressed when the parents mentioned that they would look for extra values for their children during the purchase of toys. These values were mostly perceived as something related to child development. The belief in supporting child development via meaningful play was captured in the following quote:

I guess you're looking for games that are going to do you know they're going to promote their development within that area of interest. (P3)

Despite the parents recognising the possible educational values from play activities involving electronic toys, one of the parents assumed that the values of educational toys are exaggerated.

The parents further elaborated their expectation on educational values from play by suggesting human values, history, culture, critical thinking, questioning and analytical thinking. The idea of bringing critical thinking into play was synthesised as one of the parents wished the pre-schoolers to have deeper thinking with diverse perspectives. One of the parents said that human values are important and should be introduced during play as they can guide the children to behave properly. Another parent mentioned that understanding history and culture can be meaningful values as well. Despite the various possible educational values suggested by the parents, they generally doubted the capability of electronic toys in language learning. The reasons behind, restricted dialogue and unclear audio, were seen in the following quote:

They are very restricting the dialogue isn't there, you know the voice on the toy, you can barely hear it properly. (P3)

Connecting to child development needs, parents addressed the need for opportunities that can support the development of skills. The parents suggested that their pre-schoolers needed sensory stimulation from toys. The potential of extra visual and auditory stimulation from electronic toys was also specifically addressed, showing that the parents thought their pre-schoolers could have a more sensory experience. Some parents also encouraged motor skills development via play. The motor skills mentioned by the parents included both gross and fine motor skills. The gross motor skills enabled large movement of pre-schoolers' body parts and fine motor skills enabled interactions with small objects or small features on toys. Examples could be seen in the two following statements:

... moving their body parts moving across the floor or somewhere else. (P2)

I see from my perspective is finger motor skills like fixing those stuff. (P2)

Furthermore, the need to encourage cognitive skills development was mentioned by parents. The cognitive skills included hand-eye coordination and spatial awareness as parents wished to provide more experience for pre-schoolers to learn how to move their bodies to the desired location. A parent also suggested that the need to support socio-emotional skills development included regulating emotions and understanding others' feelings via social cues. However, the parent who addressed the importance of socio-emotional development was having doubts about the teaching capability of electronic toys. The parent believed that it mostly relied on human-human interactions. The following statement summarised this idea:

I don't think we should be relying on technology, and you know electronic toys to teach emotions … you know they can only be taught through learning social cues through interactions. (P3)

Some opportunities suggested by the parents may not seem to be educational but are still recognised as important additions to holistically supporting pre-schooler development. One of the parents suggested a sense of accomplishment as a possible value. It was discovered by the parent's observation of the pre-schooler's preference for working through challenges. Another value, creativity, was generally recognised by most parents as they mentioned their encouragement of the use of imagination and the promotion of creativity in play. The parents' viewpoints on imagination are detailed in section 5.1.6.

5.2.3 Toy attributes

The parents' data on *Toy attributes* were summarised into four findings. The parents prioritised some fundamental attributes such as physical safety over some other extra values expected from toys. The parents generally wanted toys that have more flexibility in play and with a reasonable price. The parents also shared their dislikes about toys, focusing on but not limited to, electronic toys.

The parents treated four attributes as fundamental considerations for choosing toys. The most important aspect was physical safety as the parents did not want accidents to happen to their children. Another important aspect was the educational value as toys were expected to support learning in childhood. The parents wished their children could learn something from playing with toys. Specifying electronic toys, the parents liked those which can enhance sensory stimulation. Despite the importance of educational value, the fun value was mentioned as an elementary attribute for toys, as shown in one of the quotes:

I give this importance equally, fun and learning. (P2)

Thus, from the parents' perspective, toys were meant to attract children to play. Through play, the children can learn and develop. In addition, the parents wished toys to be reliable as they did not want this play and learning process to be disrupted. By considering safety and reliability, some parents, therefore, suggested that toys for all ages are preferred.

Apart from considerations of four fundamental considerations, the parents wanted toys that have more flexibility in play. The parents preferred toys for all ages and open-ended toys. They suggested that open-ended toys are good for pre-schoolers. One of the parents also mentioned that open-ended toys provide space for children to immerse themselves. This can be seen in the following statements:

You can't race, you have a limit on what you can do and something like a robot you can interact with him which traditional toy you can't like there's a limited interaction, you can do. (P1)
I mean something like LEGO you know…what I love about it is this is no restriction on you know any age can enjoy something like that. (P3)

Unanimously, the parents liked toys that were reasonably priced. This meant that toys were expected to have a value matching their price. This was mentioned in these quotes:

If it is very expensive. Then, yes, definitely allows them to choose another one. (P1)
You're looking at price and is it worth the price. So, what does it do and you know, is it actually worth the money. (P3)

Furthermore, one of the parents extended this viewpoint towards digital games. It was mentioned that microtransactions were not preferred in digital games. Microtransaction means the payments involved in pursuing additional content within applications or video games (Tomić, 2018; McCaffrey, 2019). The payments were recognised as annoying and unworthy.

Finally, the parents suggested several dislikes about toys. The parents critiqued that the electronic toys were more physically fragile. The safety associated with the internet was also questionable. Furthermore, the parents did not want the toys to have any inappropriate messages such as violent, sexist and adult content. In addition, the reliability of electronic toys was recognised to be lower as they needed battery replacement. This led to an unfriendly user experience as these toys require extra maintenance. Overcomplicated instructions were also a cause of unwelcome user experiences. As

parents were sharing their perspectives mostly based on their perceptions of what they have seen in the toy market, these negative toy attributes indicated room for improvements in existing toys.

5.2.4 Interactions

The parents' data on *Interactions* were summarised into three findings. The parents recognised that social interactions were important to pre-schoolers. The parents liked to enhance the relationships with children via interactions through different roles in play. As suggested by the parents, toy-child interactions should be continuously engaging.

The parents agreed that social interactions were essential to pre-schoolers. Social interactions were recognised as critical to child development as the parents suspected that human interaction is the only way to teach emotions. Furthermore, from the parents' observations, children mostly have interactions with each other when they are playing with traditional toys. As the social interactions were welcomed by the parents, the traditional toys were preferred in this context. The recognition of the correlation between social interactions, technology use and emotional development can be seen in the following statement:

I don't think we should be relying on technology, and you know electronic toys to teach emotions, well you know they can only be taught through learning social cues through interactions. (P3)

Carried on from viewpoints about social interactions, the parents expressed their interest in enhancing relationships with children via interactions. They thought that they should interact with their children, and it was a possible way to enhance the parent-child relationship. Imaginative play was also mentioned as an example of activities accompanying children. The bonding facilitated by play was indicated in this quote:

You can play a game with me then it's some kind of bonding as well. (P1)

Considering the forms of interactions between the parents and their children, the parents acted in different roles in play. Some parents acted in a supportive role. This included playing along with children and teaching children how to play. However, the parents often act in a supervisory role. Some parents mentioned that they will manage children's screen time and check the appropriateness of the content before letting their children play the game. Due to the limited scale of this study, the

pattern and trend of having these roles in play were unclear. However, it was recognised that parents can take different roles in varied situations.

5.2.5 Screen Time

The parents' data on *Screen Time* were summarised into four findings. The parents recognised that children's screen time had risks and benefits. It could benefit parents, yet it was possible to harm children. Therefore, management was needed for technology use in childhood, as suggested by the parents.

The parents generally suspected that screen time can be negative towards children. The parents thought that screen time can be addictive and lead to a solitary lifestyle. The excess screen time was recognised to impact on emotional development and physical development. One of the parents further observed that solitary play can impact on physical health, as seen in the following quote:

that whole thing about the neck and head when you're looking down all the time. Make sure that if she's watching it, that she's aware of where she's positioned (P3)

Apart from the negative side of screen time, the parents shared their insight on learning via screen time. Screen time was recognised as a beneficial learning process for children. Some parents claimed that videos can help children to learn languages. However, the examples given by the parents were mostly educational programs on tablets instead of toys. One of the parents elaborated this concept by mentioning that screen time can help children with special needs. The parent explained that visual cues such as sign language on screen can help children with a hearing disability.

Beyond the benefits solely for children, the parents suggested that screen time can benefit both children and parents. By giving children solitary screen time, the parents thought that let children develop independently. Meanwhile, parents also mentioned that children's screen time can let parents work on their own things. This was noticed in this quote:

If I have a time, I definitely wanted to play with them and if I'm stuck with some other activity, I will ask them to play themselves. (P2)

Ultimately, the parents recognised that technology use involving screen time was attractive, but it should be managed. The parents observed that screen time can attract children's attention. However, because of the possible negative impacts from screen time, the parents thought that children should have a balance between technology use and other activities. Some parents, therefore, claimed that they would manage children's screen time, as shown in the following quotes:

I kind of put like an hour to so that is there's not too long screen time for him. (P1)
Other toys we don't have any restrictions, except the iPad, there is, a restriction. (P2)

5.2.6 Safety

The parents were worried about the physical, content and privacy safety associated with electronic toys. The parents wished that the toys would be physically safe. As physical hazards can pose an immediate danger to children, the need for physical safety became fundamental. Apart from this generic need for physical safety in all toys, the parents shared additional concerns about electronic toys. The parents addressed their concerns about offensive content. For example, a parent mentioned that some games may be visually appealing to children, but it was made for adults. Therefore, the parents wished that electronic toys can be free of violent and sexual content. Moreover, the parents are also concerned about the safety associated with the internet. As some electronic toys had internet access, parents worried about leaking their information to others or getting their children to be exposed to inappropriate content on the internet. Therefore, the parents wished that the electronic toys would have assurance on privacy safety, and this can be seen in the following quote:

Maybe you can do everything with the Internet. whenever it's connected to Internet it's letting out your control (of) it, somebody can pick it up. (P2)

5.2.7 Imagination

The parents preferred the use of imagination in play, and they thought that children preferred it as well. The parents observed that their children like to imagine. Moreover, through imaginative play with children, relationships with children can be improved, as suggested by one of the parents. Furthermore, some parents wished to promote creativity. Therefore, play that can activate imagination was preferred. This triggered parents to share insight that toys should provide space for imagination. One of the parents mentioned that open-ended toys can provide space for children to immerse themselves. It was suggested that electronic toys can let children escape from reality, as seen in this quote:

I think sometimes electronic toys can be maybe good for children that don't have safe environments and they can almost escape for a little while. (P3)

5.3 Phase 1 data from child development specialists

The specialists' data on pre-schooler toys were categorised into five themes: ***Impacts from technology, Interactions, Toy attributes, Play activities and Values from play***. Each theme represented a specific angle on specialists' expectations on and concerns about pre-schooler toys and children's interactions with others. The following table briefly lists the major findings gathered from child development specialists in Phase 1 of this research.

Table 6: Findings of Phase 1 data from child development specialists

Themes	**Child development specialists' viewpoints**
Impacts from technology	Technology use in early childhood was harmful in many ways
	Technology was potentially beneficial as it can provide extra features compared with traditional toys.
	Improper parental behaviours can be the cause of harmful technology use.
Interactions	Human interactions were essential and beneficial to child development.
	Adults should be involved in play and support children.
	Toy-child interactions should be developmentally appropriate.
Toy attributes	Usability, reliability, and safety were the most critical aspects of toy design.
	Misleading content in toys should be avoided.
	Age range defined the appropriate types of play.
	Toys should provide both fun value and support for child development.
Play activities	Play activities should encourage the use of imagination.
	Play should provide real-world stimulation.
	Children should have a balance between technology use and other activities.
Values from play	Play should provide repeated but diverse opportunities for developing different skills.
	Toys as tools used in play, should support children's socio-emotional and motor skills.

	toys should be flexible in play to drive more imagination from children.

In *Impacts from technology*, the documented data described both potential pros and cons of implementing technology in early childhood. However, their viewpoints were mostly negative, and they think parental behaviour is one of the reasons causing the detrimental impact of technology misuse. In *Interactions*, the data reflected what specialists thought about how children, adults and toys should interact with each other.

In *Toy attributes*, the results presented specialists' requirements for toys. These requirements often link to the suspected influence from toys. In *Play activities*, the result described the specialists' suggestions for play activities. The benefits of having developmentally appropriate play and how toys should support these activities were documented in *Values from play*.

5.3.1 Impacts from technology

The specialists' data on *Impacts from technology* were summarised into three findings. The specialists suspected that technology use in early childhood was harmful in many ways. The specialists suggested that improper parental behaviours can be the cause. The specialists made their comments mostly based on their perception on electronic devices that include screens.

Uniformly, all specialists thought technology use can potentially impact child development adversely. Cognitively, screen time was related to short attention span, causing children to be easily distracted. From a socio-emotional perspective, screen time also discouraged emotional development which caused some children to have difficulty with emotional regulation. Technology use, therefore, led children to have inadequate skills in expressing themselves and understanding others' emotions. The discouragement from technology use was also applicable to physical development as children were supposed to be relatively inactive while playing with electronic toys. Missing opportunities to explore the real physical world and use real tools led children to have difficulty developing motor skills. Technology in early childhood also suppressed the use of imagination as some electronic toys were not providing flexible play.

Nevertheless, technology was potentially beneficial as it can provide extra features compared with traditional toys. These features can enhance sensory stimulation which is positive for child development. Thermal, acoustic and light cues were common features that electronic toys can provide additional support to child development. This can be explicitly seen in the following quote:

... oven toys that children use that makes noise that has actually similar picture to a real oven, and they can lit(light) up, they can make a bit warm inside, you can actually pretend to be a real oven so like those features it's good for the children because they can actually experience a bit more in the real world. (C3)

Controversially, the specialists suggested that the impacts from misuse of technology were possibly caused by parents. The specialists mentioned that some parents relied on one single educational toy too much and some parents even use electronic toys as babysitting devices. Under these parental behaviours, children failed to have a variety of activities when they were addicted to screen time. As applications in electronic toys cannot comprehensively support child development, excessive screen time would cause a delay in child development. For instance, children would not have the opportunity to develop problem-solving skills in real life. Some examples were given in the following dialogue:

We see a lot of children that are heading to Grade one they don't know how to fold a piece of paper in half, they don't know how to hold scissors and cut. They don't they haven't established their problem-solving skills, without the use of a screen that they can cry, and they become highly frustrated. (C2)

5.3.2 Interactions

The specialists' data on *Interactions* were summarised into four findings. The specialists thought that human interactions were essential and beneficial in childhood. Adults should interact with children during play and toys should interact with children in a developmentally appropriate way.

The specialists claimed that human interactions were essential to child development. Children learned from adults actions which can be positive or negative depending on the action. Some good human interactions were recognised as an element for fostering child development. For instance, the interactions with a human were particularly critical for language learning.

Children need to make better eye contact with their caregiver to learn to develop speech. (C3)

Elaborating on the importance of human interactions, the specialists claimed that these interactions were beneficial. They can help adults to understand what children think. The understandings were

important to keep track of what was happening to children. Adults can therefore provide support accordingly. Human interactions can also enhance relationships with children, as seen in the following statement:

As long as there is an interaction between the adults and the child, they will develop a better relationship. (C3)

Further explaining child specialists' viewpoints in human interactions, adults should become involved in play. Adults should have a role in supporting children. The specialists suggested that parents should set up a learning environment for children and parents needed to engage with children in play. To practically encourage human interactions, a specialist suggested sharing attention on the same object.

Finally, toys should interact with children in a developmentally appropriate way. It was commonly recognised that inappropriate language or content should be avoided in toys. Extended from the idea of encouraging human interactions, the specialists suggested that toys should encourage eye contact with others. One of the specialists also suggested adults put toys near eye level to facilitate eye contact, as noticed in the following quote:

One way is getting down to the child's level or holding up a toy at your eyes. (C1)

5.3.3 Toy attributes

The specialists' data on *Toy attributes* were summarised into six findings. The specialists thought usability, reliability and safety were most important to consider for toys. Apart from physical aspects, misleading content from toys was worth noticing as well. In addition, the age range of a toy was determined by the type of play. Generally, the specialists thought that toys should be fun but also able to provide features to support child development.

Usability was recognised as an important aspect of toys. Toys should be challenging but not too hard to use for children. By going through different challenges, children develop various skills. The developmental milestones suggested what challenges children should have at different ages and what they were capable of. Relevant literature was provided by the specialists.

The reliability of toys was important to caregivers. Electronic toys were recognised as difficult to maintain and require regular battery replacement. Electronic toys would fail to serve when they run

out of electricity. Electronic toys were also expected to be less durable than traditional toys. Therefore, the specialists suggested that electronic toys were less reliable than traditional toys. This can be recognised in the following quote:

like what if the battery is flat during my assessment…(C1)

The safety of toys was particularly important when considering toys. Unsafe toys can pose a danger to children and cause injuries. Electronic toys were criticised for the need for extra caution. One of the specialists further suggested that batteries in electronic toys may cause safety issues. This can be seen in the following quote:

If the kid accidentally put the battery in his or her mouth things like that it's like a game of safety and risk then. (C1)

Continuing the discussion on toy safety, misleading content in toys was recognised to be harmful. The specialists suggested that emotional expressions in toys can be misinterpreted. For instance, children may have a different understanding of emojis compared with adults. Without human support, the content in toys may alter child development in an undesirable way. In addition, some toys may provide misleading messages via play that lead children to replicate certain behaviours that endanger themselves or others. This implicated specialists' expectations on appropriateness in toys.

Correlating with the above-mentioned important aspects of toys, the age range in toys was determined by the type of play. In consideration of usability and safety, the age range marked on the toys was mostly determined by the type of activities suitable for the targeted group of children. For example, open-ended toys were good for children over 2 years old. In addition, traditional toys were criticised for having a relatively narrow age range as one toy mostly serves for one type of play only. This can be seen in the following statement:

Traditional toys – Kids may get bored of it as they are older I suppose. (C1)

Finally, the specialists argued that toys should be fun but also able to provide features to support child development. Toys were recognised to be used in play therefore toys should be fun-value oriented. However, toys should have features providing stimulation that encouraged development. For instance, toys with tactile feedback can help develop finger strength, as suggested in the following statement:

There's not enough tactile feedback in those buttons. I would like to see kind of more clicks more need

to put pressure three buttons. So that they actually can develop their fingers strength in. (C2)

5.3.4 Play activities

The specialists' data on *Play activities* were summarised into three findings. The specialists thought that play activities should encourage children to use imagination. Since play should involve a real-world environment, children should have a balance between technology use and other activities.

Play activities should encourage children to use their imagination and share their thoughts. The specialists suggested that pretend play and construction play would be welcomed by children. Show And Tell was also suggested for providing opportunities to practise social skills such as eye contact. The suggested play activities resonated with the relevant literature on socio-emotional development of pre-schoolers. The specialists' and children's preferences on these activities can be seen in the following quote:

They like to use those things to create their own thought and then to have more discussions… So I guess the most preferred the activities that you will use to incorporate the learning and developmental values will be show and tell and roleplay and the pretend play and storytelling, I guess…(C3)

Further explaining the suggested context of play activities, play should involve a real-world environment. The specialists claimed that children needed to explore the surrounding environment. During this exploration, children learned by engaging with real-life experiences. The obtained sensory experience can also let children be aware of dangers. The irreplaceable sensory experience implicated that real-world stimulation should not be eliminated in play.

Lastly, children should have a balance between technology use and other activities. The specialists recognised that children needed physical challenges in childhood. Existing electronic toys in the market generally failed to deliver these physical challenges. This can be seen in the following statement:

They become highly frustrated from using their hands physically because they're just used to kind of pointing dragging something on a screen. (C2)

This negative perception on electronic toys extended to failure of facilitate interactions via play. The specialists suggested that pre-schoolers should have cooperative play. However, electronic toys were

recognised as tools solely for solitary play. Therefore, the specialists suggested children should also be involved in conventional activities rather than completely immersing themselves in technology.

5.3.5 Values from play

The specialists' data on *Values from play* were summarised into three findings. Fundamentally, play should provide repeated but diverse opportunities for developing different skills. The specialists thought that play activities should provide value in supporting children's socio-emotional, motor skills development and use of imagination. These values led to their expectations upon toys.

Elementally, the specialists thought that pre-schoolers needed to develop a set of skills before going to school. For example, pre-schoolers needed to develop sensory skills, daily living skills and problem-solving skills in real-life. However, some electronic toys can discourage real-life related skills. Although pre-schoolers needed to develop a variety of skills, the specialists also mentioned that children learn skills via repeated practice. Some skills may take months or years to be fully developed, as indicated in the following quote:

So children don't learn something in once we have to go practice so many times. (C3)

Continuing the discussion on practically supporting child development, the specialists recognised play as a way for pre-schoolers to develop socio-emotional and motor skills. Toys as tools used in play, should therefore support children in this context. For instance, toys should support the development of hand-eye coordination and manipulative skills. The expected values from toys about motor skills developmental can be seen in the following statements:

Some toys that are small can support fine motor skills – like grasp, moving objects with fingers. (C1)
The kids are just using toy phones and toy cameras they don't have good clicks in there they're mimicking … the devices that we use these days so because of that the toys are lacking good manipulative skills that you need. (C2)

Lastly, the specialists suggested that toys should encourage children to use their imagination. Imagination was recognised as a fostering element for developing motor and social skills. Electronic toys were recognised to be less flexible in play. The specialists therefore suggested that traditional toys can drive more imagination from children. This perception can be seen in the following statement:

Probably with more low-tech traditional toys that helps develop your imagination that drive your imagination in play. (C2)

5.4 Phase 1 data from designers and findings on their design process

The designers' data were categorised into three themes: *Understanding stakeholders, Defining problems and Creating solution*s. Each theme represented the data about what the designers did and thought on a specific process in designing solutions for the parents and child development specialists. In *Understanding stakeholders*, the documented data described what designers needed during the first stage of the design thinking process, which is about empathising with the parents and specialists. In *Defining problems*, the data reflected how designers synthesised their understandings of the parents and specialists and thus defined the problems. In *Creating solutions*, the data showed what ideas the designers made for solving the defined problems and what they need in order to create better solutions. The following table briefly lists the major findings gathered from designers and the design process in Phase 1 of this research.

Table 7: Findings of Phase 1 data from designers and the design process

Themes	**Designers' viewpoints and findings from the design process**
Understanding stakeholders	Designers had difficulty finding the most essential needs from a wide range of needs.
	A more comprehensive and cooperative framework was needed in conducting the design process.
Defining problems	The first problem was how to guide the stakeholders in making the decision and/or evaluation of the child's development progress.
	The second problem was about how to share information among the stakeholders.
Creating solutions	The designers tried to create toys that support child development.
	The designers tried to aid stakeholders to make decisions.
	The need of the viewpoint from toy makers' perspective was addressed.

5.4.1 Understanding stakeholders

The designers' data on *Understanding stakeholders* were summarised into two findings. The designers could understand a wide range of needs from the parents and child development specialists,

but they had difficulty finding the most essential needs. To facilitate a better result from the design process, they suggested some improvements on the design framework.

Unanimously, the designers noticed the need for understanding the most essential needs from the other two groups of stakeholders. The designers noticed the need for helping carers to engage and support children to develop skills, values and concepts. They also knew that the stakeholders worried about content safety, privacy issues and negative impacts on child development arising from technology use. These understandings were synthesised into personas such as the persona (Figure 14).

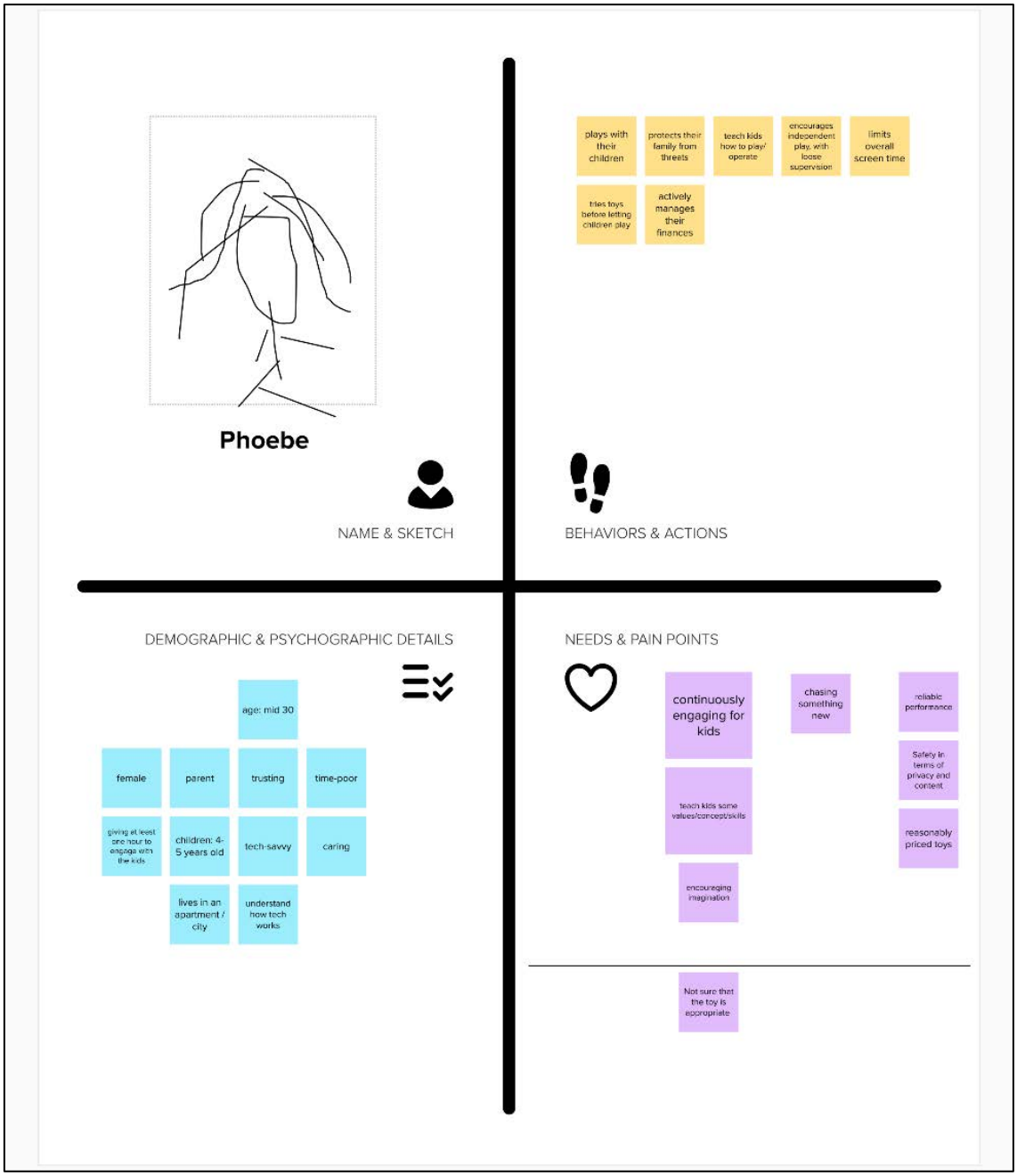

Figure 14: A proto-persona constructed during the design workshop

The designers valued the importance of parent-child interactions, but they later interpreted the stakeholders' needs as knowing suitable toys for children, which neglected the interactions with children. The designers concluded that they wished to know more about the priority on the stakeholders' needs. This can be noticed from the following statement:

It is very difficult to capture the point the exit from the three of the different categories. (D3)

Reviewing the collected data from the parents and specialists, the designers suggested that they need a more comprehensive and cooperative framework in conducting the practice project. Constant member-checking with stakeholders during the design process was needed. The designers mentioned the need for achieving mutual understanding among stakeholders. The designers believed that a more cooperative framework can help resolve conflicting needs among different stakeholders. Therefore, the designers suggested having a co-design framework with stakeholders to ensure that the outcome can satisfy the needs of the target users. The suggestion was given in the following quote:

So, not just to be involved not just to be contributing ideas, but they also learn the process to move on the same page as one, so I think on high side if. We can get them all together…We might be able to hit our goal clearer. (D1)

5.4.2 Defining problems

The designers defined the problems in two different directions. The first direction is about how to guide the stakeholders. One of the defined approaches was about helping stakeholders to make decisions. For instance, the designers suspected that the parents needed to know more information to make buying decisions. Another defined approach was about helping evaluation of child's development progress. The evaluation results were suspected to help child development specialists and parents to adapt their caring or parenting style towards children.

Another direction is about information delivery. One of the defined approaches is about transferring children's information to carers. The designers were trying to solve the problem with a system that can automatically transmit children's information captured by the toys. A similar approach was also suggested to share information among stakeholders, including their viewpoints towards different toys. The direction about information delivery were noticeable in the selected HMW questions (Figure 15).

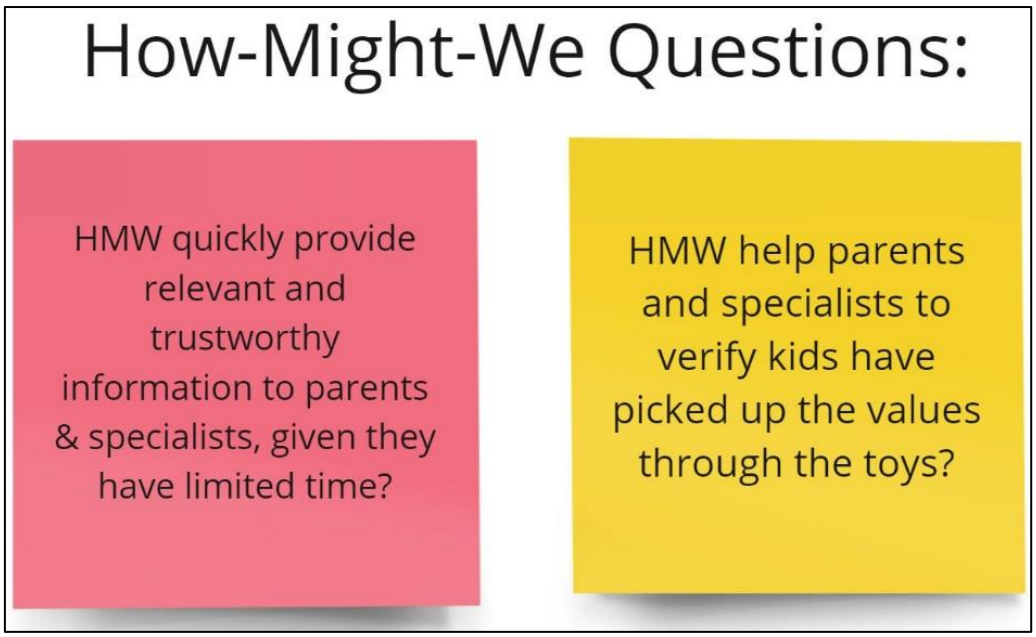

Figure 15: HMW questions constructed during the design workshop

5.4.3 Creating solutions

The designers' data on *Creating Solutions* were summarised into three findings. The designers tried to create solutions that can support child development and/or aid stakeholders to make decisions on buying or caring. However, the designers added that toy makers' perspectives should also be considered in the design process.

Firstly, the designers tried to create tools that help support child development via play. The generated ideas were aimed to satisfy different needs of children across multiple developmental stages. Some ideas such as the one shown in Figure 15 indicated the tendency for designing toys that can grow along with children.

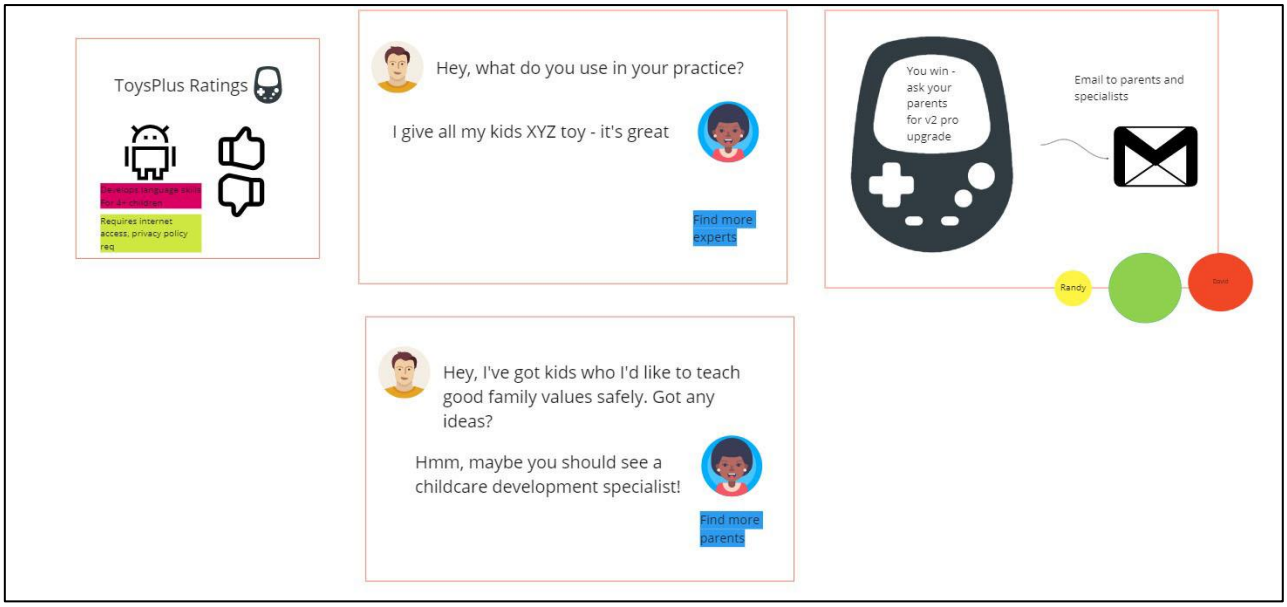

Figure 16: A sketch illustrating an idea on designing toys that can grow along with children

This approach therefore triggered the designers' need of knowledge about different play activities for children.

Secondly, the designers tried to aid stakeholders to make decisions. There was an idea about monitoring the child developmental progress automatically (Figure 17).

Figure 17: A sketch illustrating an idea on aiding stakeholders to make decisions

This idea was aligned with the defined problem about guiding stakeholders with children's information. Moreover, the designers tended to ideate solutions that transfer advice to parents. This was also aligned with the previously defined information delivery approach.

Finally, the designers addressed the need of the viewpoint from toy makers' perspective. The designers mentioned that time and cost should be considered in the design process. They also needed information about technical limitations and knowledge about safety standards. This is not only for themselves but also for parents and child development specialists. The designers therefore suggest implementing toy makers as another group of stakeholders to the project. The suggestion can be seen in the following statement:

they are not aware that how many gadgets are involved to making this scenario, feasible. (D3)

5.5 Phase 1 data summary

The Phase 1 data analysis indicated that the parents and child development specialists have some contrasting viewpoints. Both groups of stakeholders recognised the importance of toys in supporting child development. The themes found from both set of data are similar, indicating that both groups had comparable concerns about toys, play and child development. Focusing on the toy attributes, both the parents and specialists addressed their needs on supporting child development with toys, but parents had wider needs such as price and flexibility in play. The most significant viewpoint difference among all theme, was noticed in "Technology". The parents generally recognised that technology can be beneficial to children and parents with well-managed screen time. However, the specialists perceived that the technology is not necessary for child development and there are risks on having technology use in early childhood. This clash posed a challenge for novice designers to deal with in the toy design process.

The novice designer's data in Phase 1 indicated that the designers noticed the parents' and specialists needs but were having difficulties in identifying critical ones. It was noticed that the design directions and solutions were not completely aligned with the critical latent needs from parents and specialists. However, it is noticeable that the novice designers attempted to find the balance between the contrasting viewpoints and create solutions to mitigate the conflicts among differing needs. The novice designer data further suggested that a framework for better collaboration with the stakeholders was needed.

5.6 Phase 2 data: Designers' viewpoints on preliminary guidelines

The findings in Phase 1 were interpreted into guidelines with support from relevant literature. In respond to the findings that designers needed a comprehensive framework for conducting the design

process, the guidelines included design thinking knowledge (Krause, 2018; Gallagher & Thordarson, 2020). A Player, Learner and User Model was introduced in the guidelines to further mitigate designers' difficulty in finding essential stakeholders' needs and in design validation in satisfying those needs (Markopoulos et al., 2008). As designers needed information about technical limitations and knowledge about safety standards, the set of preliminary guidelines also directed readers to relevant documents to aid in ensuring toy safety when designing toys (Standards Australia Limited & Standards New Zealand, 2016; ASTM International, 2017).

The designers recognised the set of preliminary guidelines as a satisfactory outcome. It was recognised to be a beneficial read for novice toy designers before constructing their design projects. This can be seen in one of their quotes:

I think this is a good starting point again if you having this workshop executing. (D4)

However, the designers also suggested that a fraction of the guidelines needed clarification or further development.

The designers addressed the importance of highlighting the target audience and possible contributions from the guidelines since the set of guidelines was initially intended to help a very specific group of people. Letting the reader understand what it was made for was fundamental to prevent misunderstanding and confusion. This correlated to the possible contribution of the set of guidelines, which was questioned by the designers as seen in the following statements:

Is people really going to look at it, or who is going to look at it, that part wasn't clear, at least from what I see here … I really hope to see is, so where's my input is going to be in. (D1)

The discussion on this issue was extended to how to make the guidelines understandable to the target audience. Since this study aimed to aid novice designers, the readers may have limited knowledge about the design thinking framework and its corresponding tools. Considering the circumstances, the designers advised clarifying the aims and expected outcomes of each phase involved in a design project. It was confusing for designers to follow the described directions and construct their design activities without knowing the actual purposes behind them. This can be seen in the following dialogue:

What's next, and you know how is this going to be so-called like important or gonna be use. that part wasn't that very obvious to me. (D1)

I don't really know what direction that you want us like me and all the designers to be going to the right outcome that you wishing us from. (D4)

Expanding the idea of providing aid to novice designers, it was mentioned that some circumstances such as a co-design setting, may involve stakeholders in the design process. The jargon used in the design thinking framework may cause misunderstandings and negative feelings towards the stakeholders. This can halt sharing and commenting on ideas among the team. Therefore, the designers suggested explaining the jargon and noticing the readers adjust the wordings to be understandable and positive to stakeholders correspondingly. However, the goal of adjustment should be initiated from the expected research outcome instead of an academic perspective. This idea can be captured in the following quotes:

You adopt a framework but sort of jargon are meant for people in the industry who understand that we call it problems, but the parents would take it very differently. (D1)

If that's parents or stakeholders … just making that the term for to the easy understanding … Again, the outcome that's, the most important thing, rather than explain it over and over, trying to get people on the same page. (D4)

Continuing from the discussion on how to effectively convey the messages for quality outcomes, the designers suggested using examples for a more intuitive explanation. Usage of examples was recognised as a feasible way for the explanation, both in the guidelines and in actual design activities. This was implicitly shown in the following statements:

It's probably when you have a few, for example, you put some justification about what you suggest. (D1)

Can we have some examples as well? so I know what are you after or trying to say, this could be abstract. (D4)

Another suggestion for illustrating the process was the use of graphs. As noted by one of the designers, people prefer visual presentations over pure text. Having graphs in the guidelines may aid the designers to understand how to run the process and the corresponding expected outcomes.

The designers recommended including instructions on interacting with participants, including designers and stakeholders. A designer suggested that motivating stakeholders to join the design project can be started by telling them the aim of the project. The proposed aim can be advocating certain issues and/or making a contribution to society. This can be seen in the following example

given by the designer:

You have to tell them like why you do this at the very first place and could be like you're trying to help the children nowadays having these healthy environments, where they enjoy the toy. (D4)

The designers further suggested forming a reciprocal relationship with the participants to create an additional drive for participation. For instance, a designer recommended giving coffee vouchers to whoever finished the design activities. The designer claimed that the participants would feel like they need to contribute something to recompense the benefits.

The designers also suggested ways to hold the team together. Having multiple time slots for the same design activity was recognised as an effective way to keep engaging the participants with varied schedules. This synchronised with the suggestion from another designer on including some guides about preventing the drop of participants in design projects. This can be seen in the following statements:

Oh, I can commit two hours you know, every week, maybe that week my child is sick or whatever reason or content, you know, then you have to drop, so there could be some sort of way to help the mitigate on this. (D1)

Maybe having these like multiple time slots for people to choose from and also be like having the same session but can be happened multiple times so people can be like join and then just find the time that could make it. (D4)

Continuing from the discussion on having flexible schedule arrangements, the designers also mentioned that using online tools can help hold the team together. According to the designers, online tools can allow real-time collaboration with the possibility of jointing people in different locations. Given the background that this study was done during the COVID-19 pandemic, the effectiveness of using online tools was recognisable. However, it was also noted that the participants should be confirmed to be familiar with the use of technology before introducing the online tools. The suggestion of adding a guide on nurturing the collaboration with online tools can be seen in the following quotes:

You're probably dealing with people in their 20s 30s so using tech shouldn't be a major obstacle for them to hop on to like the design sessions on Zoom…without dropping out too many participants. (D1)

You know whiteboarding tool that's called Miro and so allow people to collaborate in real-time … so from my experience I think it's quite effective. (D4)

Suggestions on practically handling interactions with participants were detailed. One of the designers suggested giving some documents to participants explaining objectives before having the interactions.

A clear explicit explanation created upon the receivers' perspectives can induce thinking beforehand, thus achieving more fruitful interactions. The duration of participants' attention was also recognised as an important consideration for conducting design activities. For instance, the designer suggested that each workshop session should be finished in two hours, preferably in one hour. This was also reflected in another suggestion on understanding stakeholders. The designers suggested using surveys as a way to collect stakeholders' viewpoints. In the context of designing a survey, putting a few open-ended questions at the end can make the participants feel easier. The designer further implicitly indicated that depleting participants' attention at the very beginning of the survey would lead to a poor result. The importance of maintaining attention can be noticed in the following statements:

Because having people sitting in front of the desktop for like two hours plus that would you know kind of like people can be distracted … An hour will be like the most ideal but it's hard. (D4)

The designer also mentioned implementing observations to empathise with the stakeholders, especially pre-schoolers. The observations were suggested to focus on finding pre-schooler interests in toys. This suggestion resonated with the preliminary guidelines which proposed a similar technique for grasping data from pre-schoolers.

Finally, the designers suggested reinforcing the validity of the guidelines. A designer advised including some literature to highlight the importance of proposed concepts in the guidelines. Sufficient literature should be provided to convince people that the proposed concepts were worth adopting in a design project. Another designer extended this idea to getting validation on the guidelines from different groups of stakeholders. Including toymaker and pre-schooler perspectives was recognised as potentially beneficial to a design project. This suggestion can be seen in the following statements:

So definitely have someone to talk to who is working in the industry that will be better. (D4)

It may be worthwhile to be talking to kids. (D4)

Despite the discussion on the validity, the designers believed that readers should assess and revise the methods and structures used in their projects. This was led by the belief that real-life situations can be dynamic. Therefore, continuous adaptions were recognised as important in design projects. This can be initiated by observations of the work provided by the participants, as suggested by the designers. This suggested adaptive concepts synchronised with the iterative nature of the design thinking framework used in this study.

5.7 Phase 2 data summary

The designers recognised the potential and usefulness of the set of preliminary guidelines. However, presenting the guide required further work and there were missing gaps found in the set of preliminary guidelines. Therefore, the designers suggested adding sections suggesting how to convey the information the participants need, in form of visualisations and appropriate interactions. Apart from managing collaboration with stakeholders, suggestions for internally managing the design team were also required. The novice designers also questioned the validity of the set of guidelines. To conclude, the novice designers suggested future work on validating the guidelines and/or nurturing comprehensive guidelines with deeper study. The designers' suggestions for improving the set of preliminary guidelines, which served as the input for Phase 3 of this research, are briefly listed below.

- The set of guidelines should let the reader understand what it was made for to prevent misunderstanding and confusion.
- The guidelines should clarify the aims and expected outcomes of each phase involved in a design project.
- The guidelines should explain the jargon and notice the readers to adjust the wordings used in interactions with stakeholders to be understandable and positive.
- Both in the guidelines and in actual design activities, examples should be used for a more intuitive explanation.
- Graphs should be added to the guidelines that may aid the designers to understand how to run the process and the corresponding expected outcomes.
- Instructions on interacting with participants, including designers and stakeholders, should be added to the guidelines.
- The guidelines should suggest designers form a reciprocal relationship with the participants to create an additional drive for participation.
- The guidelines should suggest ways to hold the team together.
- The guidelines should give suggestions on practically handling interactions with participants.
- Literature support should be added to reinforce the validity of the guidelines.
- The guidelines should suggest readers assess and revise the methods and structures used in their projects.

5.8 Phase 3 data: Participants' reflection on preliminary guidelines

The set of preliminary guidelines, as documented in the Appendices, was revised according to the findings in Phase 2. The revised set of guidelines was then presented to all participants via email and online meetings. Three participants agreed to join the online meetings. Due to the length of the

research, other participants were not available because of personal reasons. The drop-out will be further discussed in section 7.3. The online meetings allowed the participants to familiarise themselves with the guidelines and get their questions answered interactively. The participants were then asked to comment on the revised guidelines. The collected feedback came from one novice designer, one parent and one child development specialist. The aim of collecting the feedback was to confirm that the set of guidelines addressed the stakeholders' needs to an extent. The data are documented in this chapter.

All engaged participants expressed a positive attitude towards the final revised guidelines. The participants recognised that the set of design guidelines is suitable for the target audience from the scope of this research. This recognition can be seen in the following quotes:

I think for toy designer point of view at this level, I think, is comfortable and sufficient. (D1)

Well, no question at this point in time it's really good Thank you. (P2)

The positive reflection provided the ground for the finalised set of guidelines, demonstrating its validity.

The designer further mentioned the concerns in motivating stakeholders to join the research. Although the designer recognised the validity of the guidelines, it was addressed that novice designers may find it hard to recruit participants. This challenge is also noticeable in the dropout rate in this research. The designer further suggested that voluntary work in design projects may not attract stakeholders to invest their effort and time. The issues of recruiting and managing participants were suggested as potential challenges in using this set of guidelines, as seen in the following quote:

Getting people managing people might be a challenge. (D1)

The designer recognised that there are gaps in the set of guidelines. Apart from the potential challenge of motivating participants, there are other neglected issues. The designer addressed that gaps are inevitable in research outcomes. However, the researcher was advised to document potential gaps and the corresponding future work. This suggestion was noticeable in the following quote:

Maybe just a few lines say that you addressed them, you acknowledged them or this may be in the future work. (D1)

6. THE FINALISED GUIDELINES

This chapter presents the finalised guidelines made as an outcome of this research. Section 6.5 describes how the findings in this research were interpreted into the finalized guidelines.

Intent

To aid novice designers who wish to design developmentally appropriate preschool toys for children aged 4-5 years old, with added values from technology not used in traditional toys.

Scope

A framework, checklist and suggestions for constructing design projects

The guidelines

Introduction

Designers should take the guidelines to construct their own design projects including three fundamental stages: Understanding Stakeholders, Defining Problems and Creating Solutions. As the stakeholders in this document generally refer to parents, and child development specialists, the last part of the guidelines demonstrates how to facilitate collaboration among them.

6.1 Understanding stakeholders

The designers should follow the fundamentals in understanding stakeholders.

Fundamentals

- Designers should conduct a study to understand stakeholder needs
- Designers should revise the methods upon observation of the responses from stakeholders
- Designers should study stakeholders from six perspectives:
    - Form of play
    - Values from play
    - Imagination
    - Interactions
    - Toy attributes
    - Technology Influence

Considerations from six perspectives

The following six perspectives demonstrate the directions and reference points for designers to study their stakeholders.

- Form of play
    - Play should be interesting, relieving, and understandable to children
    - Play should have a balanced use of technology
- Values from play
    - Values should be based on the developmental needs of pre-schoolers including motor skills, cognitive skills, sensory skills, daily living skills and socio-emotional skills
    - Educational values such as learning language and culture should be recognised as additional values
- Imagination
    - Imagination is an essential element for developing creativity
    - Toys should provide space for use of imagination. (e.g., Open-ended toys such as LEGO)
- Interactions
    - Social interactions are essential in children's socio-emotional development
    - Play experience should be interesting to children and adults to encourage adult-children interactions
    - Toys should be continuously engaging and usable by children
    - The context of interactions between toys and children should be appropriate
- Toy attributes
    - Toys need to be safe, reliable, usable, beneficial, and fun for children
    - Stakeholders' judgements on price are made upon the performance of the above-mentioned factors
- Technology Influence
    - Technology is appealing to parents and children, but child development specialists have concerns about the addictive screen time
    - Conflicts between two groups of stakeholders may be solvable by giving alternative methods for augmenting toys with technology without screens.

6.2 Defining problems

In defining guiding questions for facilitating brainstorming in later stages of a design project, designers should consider the following fundamentals.

Fundamentals

- The questions should be defined in a way that guides the designers to solve the problem with toys
- The questions should not include the involvement of technology
- Designers should define sub-questions to tackle various requirements
- Designers can start with defining sub-questions for designing play, with one type of play for each question
- Designers should primarily consider the needs related to child development
- Designers should utilise their understanding in:
    - Form of play
    - Values from play

- Imagination
- Interactions

Examples for guiding questions

Designers should create guiding questions having structure, depth, and broadness similar to following examples.

- "How might we support fine-motor skills development in toys?"
- "How might we enhance the sensory stimulation in toys?"
- "How might we encourage collaboration in social play?"
- "How might we help pre-schoolers immerse themselves in pretend play?"

6.3 Creating solutions

Ideating, prototyping, testing and iteratively revising the solutions are essential. In creating solutions, designers should consider the following suggestions in different stages.

Ideating stage

- Designers should use guiding questions for hosting activities that seek divergent ideas, for example:
  - Crazy 8s: each designer creates eight conceptual solutions in eight minutes
- The design team should use decision-making activities such as voting to converge ideas
- Designers should use ideas evaluating activities independently instead of in group session, for example:
  - Evaluate ideas from six perspectives (i.e., Six Thinking Hats):
    - What is the current information on the idea?
    - How does everyone feel about the idea?
    - What are the positive aspects of the idea?
    - What are the negative aspects of the idea?
    - What are new alternatives for solving the problem?
    - What conclusions can we make in moving forward on the idea?
- Designers should continuously observe the performance and revise both the ideas and design activities

Prototyping and Testing Stage

- Depending on the guiding questions and ideas, varied prototyping methods can be used, for example:
  - Detail storyboards illustrate problem, solution, and benefit:

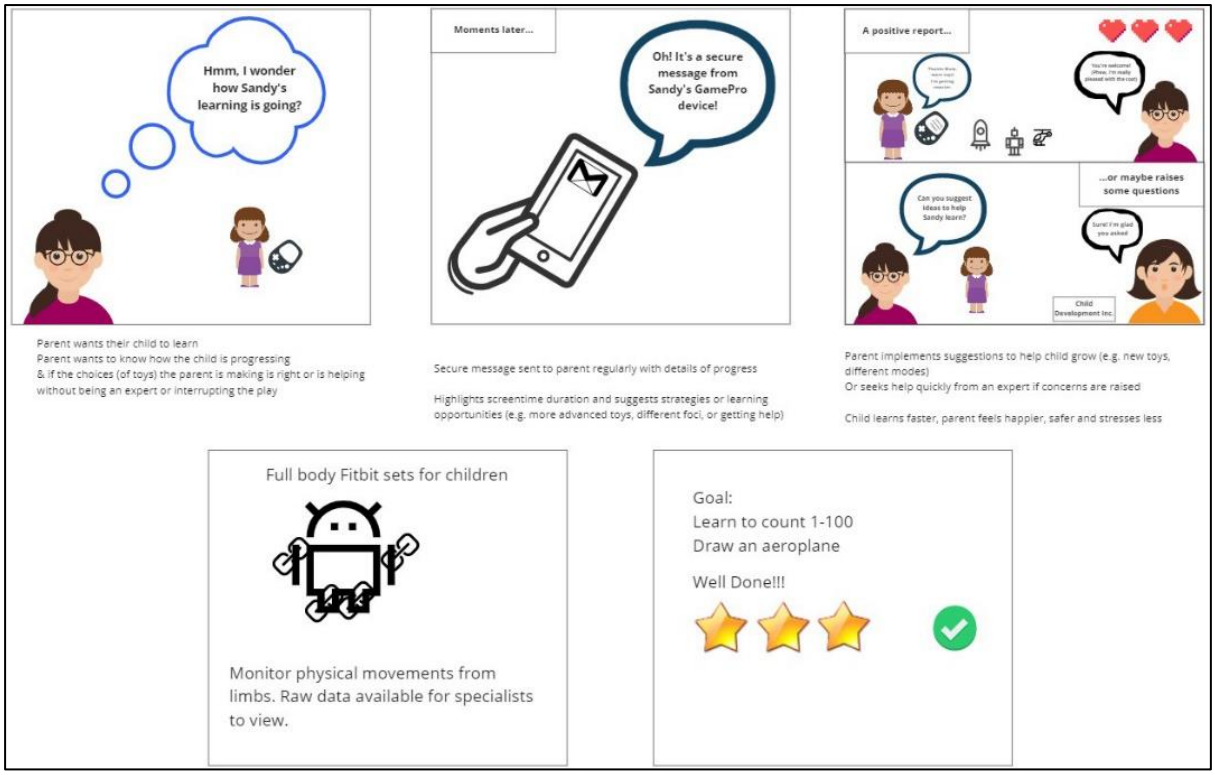

Figure 18. Example of using detailed storyboard as prototype

  - Paper/other lightweight prototypes (Wizard of Oz) test the user experience of the toy
  - Mood boards test how sensory stimulation satisfies the users' emotional needs
  - Tactile, playable prototypes (late prototype only)
- Collected feedback should be used to iteratively revise the idea
- Designers should utilise their understanding of the toy attributes and technology influence
- The design team should ensure that the prototype is complying with safety standards such as AS/NZS 8124
- Designers should observe with parents and child development specialists on children's play with the prototype
- Designers and stakeholders should review and evaluate the performance of entertainment features, education features and enabling features based on their observation of children's play with the prototype.

6.4 Approaches to maintain quality collaboration with stakeholders

Designers should maintain quality collaboration with stakeholders at all stages of a design project by using the following strategies. To develop a solid team with stakeholders, designers should first motivate participants to join the research, then designers should try to maintain the team attention in joining it. Throughout the whole process, the designers should be mindful about the wordings in interaction, and the designers should be iterative across all aspects and stages of the design project.

- Motivating participants
    - Designers should inform the participants about the aim, how the project transfers their contribution back into the society
    - Designers should form a reciprocal relationship with participants by sending gifts
- Maintaining attention
    - Designers should provide multiple time slots for each design activity
    - Designers should use online tools such as Miro and Google Sheets to facilitate the design activities after confirming that everyone is comfortable with it
    - Designers should respect participants' time by hosting each design activity within two hours, preferably within one hour
    - Designers should provide documents explaining the objectives of the design activities beforehand
    - Designers should avoid the use of structure and methods that deplete attention early in the design activities
- Being mindful about the wording in interaction with stakeholders
    - Designers should translate and explain jargon from the industry such as "technology" and "electronic toys" in a simple and understandable way
    - Designers should use visual language such as graphs to convey messages
    - Designers should avoid the use of words like "problem" and "issue" that pose negativity towards the children
- Being iterative across all aspects and stages of the design project.
    - Designers should have stakeholders give feedback on their design outcomes and revise accordingly
    - Designers should review and revise the methods and structures of their projects from time to time.

6.5 Interpretation of findings

This section documents the interpretation of findings based on the scope defined by the research questions. The interpretation aided in formulating the set of guidelines documented in this chapter. With respect to the structure used in the set of guidelines, this section involved five parts: Understanding stakeholders, Defining problems, Creating solutions, Approaches to maintain quality collaboration with stakeholders, and Response to research questions.

6.5.1 Understanding stakeholders

Designers should show ancillary empathy in designing toys as children are vulnerable. Understanding parents and children is the first step to empathising in human-centred toy design. This further indicates that designers should seek first-hand quality data with stakeholders. Common sense and practices in this study dictate that participants provide more quality responses under comfortable situations. As participants' preferred methods, structures and styles can differ, designers should construct and revise the methods upon observation of the responses from stakeholders. To maintain

this flexibility, this study focused on providing directions for understanding stakeholders' needs in designers' investigation. Categorising the participants' concerns raised the participants in this study, the researcher discovered the directions in six perspectives: ***Form of play, Values from play, Imagination, Interactions, Toy attributes and Technology influence***. The findings under these perspectives in this study demonstrate an overview of the stakeholders' expectations towards toys in the current digital era.

Form of play

Form of play is structured from the child developmental and entertaining purposes. From a child development perspective, pre-schoolers have an increasing interest and need for social play and pretend play as they are getting closer to 5 years old (Hughes, 1999). Social play includes associative play where children share and communicate; and cooperative play is where children work together towards a common goal. Although adults are welcome to play with children, designers should consider that children often play with each other without adults. Therefore, play that is too complicated for pre-schoolers to understand should be avoided in toy design. Practically, along with playtesting with pre-schoolers, reading literature describing children's play behaviour is advisable in understanding how to intrigue but not overly challenge children in play. For instance, the literature published by US Consumer Product Safety Commission is relevant. It describes how children's play behaviour changes along with their ages, and how it correlates to types of play and toy characteristics (Simth et al., 2013). Concluding the specialists' standpoint, play activities should be conducted in a real-world environment as these physical interactions and stimulations are critical to child development while technology has minimal contribution to it.

Differing from the specialists' standpoint, the parents are more likely to take a standpoint of gifting an enjoyable play experience to their children. This indicates that parents focus on how to attract children to play and keep them entertained while the specialists mostly focus on how to support child development with a suitable form of play. To conclude, the difference in how parents and specialists view the form of play leaves an explorable area for designers, especially for designers who are inventing new forms of play with technology as the existing literature rarely explores its possibilities.

Values from play

Values from play should be based on the developmental needs of pre-schoolers. During preschool, children have play-based learning for accomplishing physical, socio-emotional, and cognitive skills as

tools for further academic learning (Pyle & Danniels, 2017). Child development specialists in this study also prioritise and focus on these skills' development. However, parents take a slightly different standpoint. Parents recognise the importance of skills development, but they also recognise other values such as human values, culture, history and language learning. The variation of values that parents desire to deliver via play echo with the findings in existing literature that parents' understanding of children's needs are subjective (Mowder, 2005; Liebling, 2004). Interpreting the noticeable difference with the standpoint of this study, it suggests skills' development in play is fundamental while educational values are recognised as additional values. Considering that traditional toys have been providing developmental values, adding educational values in technology augmented toys will be a way to show designers' further empathy to stakeholders.

Imagination

Imagination is a catalytic element in play. Rather than explicitly teaching children about these developmental skills, it is preferred to get children to use their imaginations in play to spontaneously gain the skills or even provide a portal for adults to facilitate the use of imagination. While the parents recognise the use of imagination as an essential element for developing creativity, it also helps increase the sustainability of toys by lifting the replay value. This finding is supported by existing literature that mentioned parents' preference on toys that can help children develop creativity and bring more unstructured play (Gardner et al., 2012). This resonated with child development specialists' view on learning via repeated actions while the unlimited possibility in play continuously enticed children to go through these repeated actions. It is notable that parents and specialists like imagination-encouraging features with different purposes. Interpreting this finding from the designers' perspective, these features have to be implemented in a way that is recognisable in satisfying for both purposes.

Interactions

Interactions, especially social interactions, are essential elements in play. The child development specialists suggest that carers and parents should play with children as human-human interactions are necessary for child socio-emotional development. Parents also like social interactions as they can enhance relationships. However, parents are not always available to play. Therefore, the play experience should be interesting to children and adults such that it can encourage but not strictly require the adults' involvement. Furthermore, parents and child development specialists expect toys to be continuously engaging with children. Therefore, designers should take reference from children's play behaviours on both traditional toys (Simth et al., 2013) and digital interfaces (Liu et al., 2018) when designing technology augmented toys. In addition, the context of interactions between toys and

children should be appropriate. Toys should not provide sexual, violent and/or misleading content that can cause children to harm others or themselves. To conclude, carefully designed human-toy interactions can be favourable in encouraging healthy human-human interactions, but designers should prevent overwhelming play with human-toy interactions by designing them in a supportive manner.

Toy attributes

Toys should be safe, reliable, usable, beneficial and fun for children. Fundamentally, parents and child development specialists need toys that secure their privacy and provide both appropriate content and physical safety. This finding supports the existing literature that indicates parents' desire for content filtering and privacy (McReynolds et al., 2017; Chaudron et al., 2018). Reliability is considered important as users wanted an unobstructed play experience. Although usability is an important need, children are expected to have some physical challenges with toys supporting motor skills development. This resonated with the specialists' viewpoints on getting children repeatedly to try and play with toys to accomplish skills. To engage children and parents to play with the toys, the toys should be appealing and fun to interact with. Considering the above-mentioned factors, the parents liked to have the toys reasonably priced. Further interpreting this finding, it means toys should have appeals and features matching the price expectations from parents. The complexity of parents' buying behaviours leaves an explorable area for designers to investigate for different communities.

Technology influence

Parents and child development specialists have very different standpoints on technology influence from toys. Technology is appealing to parents and children, but child development specialists have their concerns about addictive screen time. Parents realise that technology use can be beneficial if it is well-managed. Apart from the additional educational values, parents like to provide private time for children and themselves. This resonates with the existing literature that shows parents' general acceptance of technology use in non-educational casual play (Brito et al., 2018).

Child development specialists perceive that technology may bring additional benefits and stimulation to children, but state that technology use is not necessary. They further claim that parents' poor management of technology use can lead to addiction to a narrower range of play, especially for solitary play. The worry towards the lack of social development due to excess solitary play is shown in the existing literature, which explicitly expresses that "the use must be taking place with others"

(Daugherty et al., 2014). This indicates the potential need for supporting parents in regulating pre-schoolers' technology use, as the need of managing inevitable screen time is also mentioned by Daugherty et al. (2014). Furthermore, as these judgements are screen time oriented, the conflicts between two groups of stakeholders may be solvable by giving alternative methods of augmenting toys with technology without screens.

Using the six perspectives in toy design projects

The findings under these six perspectives provide valuable contributions in different phases of toy design projects. As toys are used as a tool in play activities, the ***form of play*** and ***values from play*** are treated as the origins of toys. ***Imagination*** should be considered as an element in these activities following ***interactions*** among adults, children and toys. Therefore, the above-mentioned four perspectives play important roles in Phase 2 of toy design projects: Defining problems. The ***toy attributes*** and ***technology influence*** are oriented around the presentable forms of toys. Therefore, they should be carefully considered in realising ideas during later stages of the design projects: Creating solutions.

6.5.2 Defining problems

Designers need more than a clear guiding question for complex toy design projects. Yet it is reasonable to start with a main guiding question. Although this study aims to help create developmentally appropriate technology augmented toys for pre-schoolers, the involvement of technology should not be included in the main guiding questions. Technologies should be considered as tools for designers to solve problems instead of being a part of the problems. For example, "How might we support fine-motor skills development in toys?" and "How might we enhance the sensory stimulation in toys?" The main guiding question can be the broad direction for the whole design project, yet later in the design project, more issues and problems will have to be resolved. Defining guiding questions for designing play can be a good start. The guiding question for play is bounded by where, who and how the toys are going to be played. For ease of getting a targeted solution and keeping it understandable to children, one type of play should be solely adopted on each toy. Designers should then define sub-questions to tackle these various requirements on toys, like safety and appeal.

Defining guiding questions helps designers to position their toys corresponding to their understandings of stakeholders. It also helps designers clarify the standpoint in their project. As

mentioned in 8.2.1, there are many explorable areas under the six perspectives. These explorable areas confused the designers in the first phase of this study. Having a clear standpoint representing the project's vision helps the designers to accelerate and smoothen their exploration. Practically, designers can utilise their findings in four elements of play: ***form of play, values from play, imagination and interactions*** when defining the guiding questions. Then, the designers should send their defined guiding questions to stakeholders and ask for feedback. The collected feedback can then be used to revise the guiding questions and/or the understanding of stakeholders' needs. Ultimately, designers should be able to situate their project in stakeholders' needs.

6.5.3 Creating Solutions

Creating toy solutions requires extra caution regarding ethical and safety issues. Fundamentally, the toy design process can follow the traditional design thinking approach which involves ideating, prototyping, testing and iteratively revising the solution. However, as toys serve vulnerable children, unethical research can hugely impact children's mental and/or physical health. In ideating for play experience, designers may try to maintain the children's attention spans on the toy, as implicitly narrated by the findings mentioned in 8.2.1. However, overly occupying the children's playtime on one toy can cause addiction. This contradicts the specialists' standpoint that children should be given diverse types of play. Although trade-off is common in design projects, it is notable that some needs cannot be sacrificed, especially for those related to child development. Furthermore, designers in conventional projects may test prototypes by informing the participants about the risk involved and the necessary precautions required. The same practice cannot be adopted in toy design projects. Pre-schoolers do not have the intellect required to understand the consequences of failure and the gravity of precautions. Therefore, designers must take full responsibility for ensuring safe testing by eliminating any foreseeable dangers. This also includes possible misuses by the pre-schoolers. Practically, designers must ensure that their prototypes comply with safety standards published by local authorities. For instance, if the prototypes are tested in the Australian community, they should comply with AS/NZS 8124 series of safety standards.

Designers should utilise their findings on ***toy attributes*** and ***technology influence*** when creating solutions. As indicated by the findings in this study, these two perspectives explicitly describe stakeholders' critical concerns on playable toys instead of conceptual products. When designers understand the stakeholders in *toy attributes* and *technology influence*, it should also include adult stakeholders' observations on pre-schoolers' play with the prototypes. As pre-schoolers may not be able to express themselves accurately, observations of their play would be more preferred than

interviews (Markopoulos et al., 2008). Observations with parents and child development specialists would be recommended for understanding children's behaviours. To simplify and visualise the expectation and actual performance of the prototype, designers can utilise the understanding of children's behaviours and plot them in the Player, Learner and User Model (Figure 18):

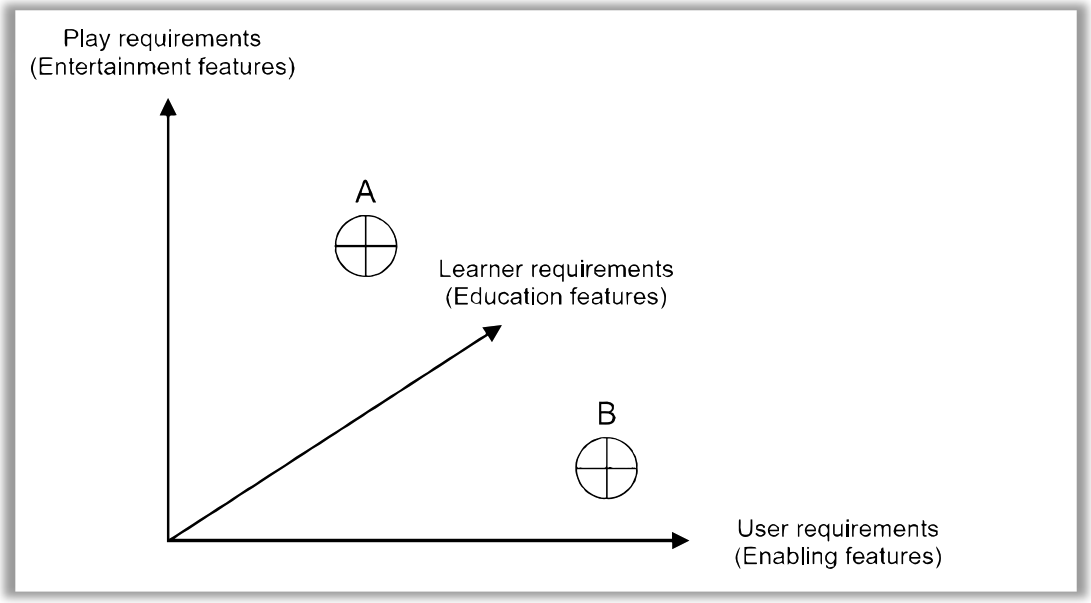

Figure 19: PLU model (Markopoulos et al., 2008)

Designers should have the stakeholders review the position of the toy in the PLU model to see whether it satisfies their expectations of toys. As mentioned in section *5.1 Understanding Stakeholders*, technology may not be necessary for education features in the PLU model, but designers can use technology to enhance the entertainment and enabling features. This does not mean technology cannot have any involvement in fulfilling learner requirements. Since developmental needs change rapidly as pre-schoolers grow up, a possible design direction would be to use technology to enable toys to shift how they support child development. However, this will not be discussed as designing toys for different age ranges would be outside the scope of this study.

6.5.4 Approaches to maintain quality collaboration with stakeholders

Quality collaboration can be started by motivating participants to contribute to the design project. The motivation can be induced by informing the participants about the aim of the project and how the project transfers their contribution back into society. The purpose of doing so is to tell the participants that their work can potentially benefit their interests. Another way of motivating participants is to

form a reciprocal relationship with the participants. Gifting something such as coffee vouchers to the participants can attract participants and/or smoothen collaboration across the whole project.

Holding the team together would be crucial after forming the team. As participants may have varied and diverse schedules, the team should have multiple time slots for each design activity. The team should also consider using online tools such as Miro and Google Sheets to facilitate the design activities if possible. However, the team should confirm that everyone is comfortable and familiar with using technology in the design project.

Designers should be mindful of wording when having interactions with stakeholders. If the design activities involve using the jargon from the industry, they should be translated and explained simply and understandably. For example, “Technology” and “Electronic toys” should be clearly defined. When it comes to the explanation of concepts, processes or terms, designers should consider using examples and/or visual language such as graphs to convey the message. In addition, it is notable that investigation of parenting styles can be very sensitive to parents. Therefore, designers should be careful about the wording when interacting with parents, especially for those related to children. For example, designers should avoid using words like “Problem” and “Issue” that pose negativity towards the children.

Attention from the participants is important to consider during interactions. This is especially important for parents as they may need to supervise their children during research activities. Referenced on the practice and the suggestions from the designers, each design activity should not exceed two hours and it is preferable to contain each activity in one hour. The host of the design activities should also provide documents to participants explaining the corresponding objectives before conducting these events. It can trigger their thinking before these events and minimise the attention and time required to understand what to do. Designers should have a similar mentality of grasping stakeholders’ attention when conducting other types of design activities. For example, designers can control the number of open-ended questions and put them at the end of a survey. This can help prevent the depletion of stakeholders’ attention early in the design activity.

Designers need to provide extra effort in organising events with parents and specialists due to their conflicting schedules. In addition, putting parents and specialists in a group discussion setting may hinder sharing of their true thoughts and their contrasting viewpoints. Therefore, some follow-up individual interview sessions for each stakeholder may be required for having an in-depth

understanding of their needs. This phenomenon and the effectiveness of the corresponding solution were recognisable in this study.

To conclude, iterations in methods and ideas are particularly advisable for novice toy designers. Due to the lack of knowledge and experience early in the projects, novice designers may not be able to produce promising outcomes. Interpreting the findings from the practice project in this study, the novice designers would be less confused through the design process if they had a chance to revise the framework in conducting the project. Therefore, continuous evaluation of the performance and corresponding revision of both the ideas and design activities with the whole design team are crucial in projects involving novice designers.

6.5.5 Response to research questions

What guidelines are appropriate for novice designers who were creating DATU toys for children aged 4-5 years old?

The interpretation of findings led to the finalised design guidelines as documented in Chapter 6. Driven by the design-based research framework, the process of getting the findings and revising the interpretations was conducted along with the novice designers. This ensures that the set of finalised design guidelines is understandable and therefore appropriate for novice designers. The data were collected from the practice project which was aimed at creating DATU toys for children aged 4-5 years old. This ensures that the findings and research outcomes match the scenario of the target audience. The novice designers' positive attitude towards the finalized set of guidelines provides grounds for its appropriateness.

The parents and child development specialists further support the potential of creating DATU toys with the finalized set of guidelines. The parents and specialists recognized that it can create toys concerning their needs. As implied earlier in section 1.2.2 in Chapter 1, the mean of DATU in toys largely depends on the needs of these stakeholders. The recognition confirms that the finalized set of guidelines satisfies this requirement. However, as this research did not have an experiment for investigating the difference between designers who adopts the guidelines and those who do not, the actual effectiveness in improving the mean of DATU in toys is unknown.

How can these guidelines address the concerns from parents and child development specialists?

Fundamentally, the guidelines encourage the audience to study the concerns from parents and child development specialists. Six perspectives are suggested as the directions for further studying the stakeholders' needs. The six perspectives are Form of play, Values from play, Imagination, Interactions, Toy attributes and Technology Influence. The investigated needs from the practice project were also documented as examples for the audience to understand these six perspectives. These examples explicitly address the detailed concerns of the parents and child development specialists who participated in this research.

Another fundamental in the set of guidelines is to prioritize needs related to child development. This research elicited that parents and child development specialists unanimously recognized supporting child developmental needs is essential for DATU-centric toys. Among the various needs expected in the research and development (R&D) processes of DATU-centric toys, novice designers may feel uncertain in defining the design directions concerning the most important stakeholders' needs, as noticed in the small design project in this research. This fundamental acts as a gatekeeping guide to ensure the outcomes of R&D processes are founded on the care for child development even after pivots of ideas.

What are the issues which must be resolved during the design process?

Issues include having difficulty finding the most essential needs, having insufficient cooperation with stakeholders, and the lack of literature support. Details of these issues were documented in section 5.4 in Chapter 5. As the practice project simulated how novice designers conduct a design process for making DATU pre-schooler toys, the documented data reflected the possible issues that must be resolved during the actual design process.

7. DISCUSSION AND CONCLUSION

7.1 Introduction

This chapter reviews the importance of research outcomes with a discussion of their limitations and implications. In section 7.2, the stakeholders' perspectives are discussed in the context of relevant literature. The findings are analysed from the raw data with the scope narrated by the research questions. The meanings of these research questions are given by the insight driven by the literature review.

The insight that initiated this research was the need to create technology augmented toys that support pre-schooler development. The industrial figures indicated a rising demand for technology use in early childhood (European Competitiveness and Sustainable Industrial Policy Consortium, 2013). However, the literature showed that technology use in early childhood should be handled thoughtfully (Brown et al., 2011; Wooldridge & Shapka, 2012; Madigan et al., 2019; Verdine et al., 2019). Common sense dictated that guidelines are recommended for designing pre-schooler toys to support child development. As parents are important to child development while being the users of toys, the guidelines can take considerations from both children's and parents' needs. The existing guidelines related to toy development are not sufficient to support novice designers in creating a solution in such a context. Therefore, a gap was identified, and three research questions were raised under the constructivism framework:

1. What guidelines are appropriate for novice designers who were creating DATU toys for children aged 4-5 years old?
2. How can these guidelines address the concerns from parents and child development specialists?
3. What are the issues which must be resolved during the design process?

The methodology for seeking answers to the research questions was grounded in the constructivism paradigm. The research gap was coming from the lack of consideration of parents' and children's needs in existing design guidelines. The investigation of stakeholders' individual needs indicated that this research is a qualitative study. As this research aimed to initiate the development of solutions by analysing the practical problem, a design-based research framework was adopted. Focused on the problem with designers' scope, the researcher facilitates a practice project with the design thinking process in the first phase of the research. Parents and child development specialists were involved in this practice project.

In the first phase of this research, the designers found that parents and specialists had similar viewpoints in general but diverse standpoints on technology use in early childhood. The designers sought a balance between these critical differences and created conceptual solutions for the practice project. The holistic observation of the design process along with the reflections from designers was documented as designers' data. All recorded data from the first phase are recorded in Chapter 4. The collected data were then synthesised into a set of preliminary guidelines with support from the literature. In the second phase of this research. another round of data collection was completed to gather designers' feedback on the set of preliminary guidelines. The data indicated there is room for improvement, especially in suggestions for collaboration with stakeholders. These findings were documented in Chapter 5.

Interpretations of the findings from Phase 1 and Phase 2 were made to create guidelines documented in Chapter 6. The set of design guidelines was synthesised from the participants' viewpoints and relevant literature. The discussion of participants' viewpoints discovered in this research is shown in section 7.2. Interpretations of the data and reasonings behind the synthesis were structured into four main parts under section 7.3, corresponding to the four main sessions in the set of design guidelines. The limitations of the study are documented in section 7.4. Industrial and academic implications of the findings were documented in sections 7.5 and 7.6. The recommendations for future work are in section 7.7.

7.2 Discussion of stakeholders' viewpoints on DATU-centric toys

The origin of this research was the uncertainty of stakeholders' expectations of DATU design in toys. This uncertainty formed the problem statement and research questions. Therefore, this research investigated the viewpoints related to DATU-centric toys from two groups of stakeholders: parents and child development specialists. These two groups of stakeholders have similarities in attitudes towards DATU-centric toys, but they originated from different standpoints. This section will demonstrate the discussion of the findings elicited from the analysis of these stakeholders' viewpoints.

The parents expected DATU-centric toys to help create a nurturing and harmonizing environment for both children and parents. The parents perceived that such an environment should encourage and support the children from multiple angles, as documented in section 5.2.2 in chapter 5. These angles

can vary from each individual with the most universally agreed aspect being the development of skills similar to what child development specialists suggested. The diverse angles emerged from parents' visions on their children. This insight resonates with the existing literature that demonstrated the complicated parents' preferences which are influenced by diverse factors (Al Kurdi, 2017). Therefore, beyond the fundamental child development, the parents wish to have DATU-centric toys to further support their children's growth in ways that parents find meaningful.

The harmonizing elements in such an environment revolved around the fun, safety, interactions, and freedom in play. The meaning of fun in play should depend on the children's interest as one of the important attributes, as implied by the parents equally weighting the importance of fun and learning in *Toy attributes,* which was documented in section 5.2.3 in chapter 5. Compared to traditional toys, parents were more careful towards toys involving new technology, especially for those having access to the internet. This insight further consolidates the model of parents' toy-buying decision which highlights the safety and emotional-related factors simultaneously (Al Kurdi, 2017). Despite the extra amount of effort ensuring the appropriateness of toys, the parents recognized that the values of DATU-centric toys are worth their effort.

Considering the aspect of interactions and freedom, parents wanted to have flexibility in parent-child and child-toy interactions. For parent-child interactions, parents often vary from supportive roles and supervisory roles in different situations and availabilities. As mentioned by the parents, they also had to work on things other than playing with their children. Although the parents loved to spend time with their children, the parents found it easier if the DATU-centric toys can offer flexibility between solitary play and social play. For child-toy interactions, the parents preferred letting their children freely explore the possibilities in play, as implied by their preference in open-ended toys. This freedom in play provided space for imagination, which was liked and needed by children. This space further provided opportunities, in terms of interactions, for parents to share their thoughts and reinforce their relationships with their children. The requirements on space and flexibility in interactions are in-line with the top three important factors in toy selection as documented in the relevant literature (Al Kurdi, 2017). Converging the parents' needs in DATU-centric toys for creating a nurturing and harmonizing environment, the parents wanted to try different ways to support their children's well-being in their present and also in the future.

The child development specialists expect DATU-centric toys to help create a supportive environment for children. In terms of support, the specialists' foci mostly circled the child development skills. As

documented in section 5.3.5 in Chapter 5, the child development specialists expressed their perceived values from play mainly as fostering socio-emotional skills and motor skills. These foci were grounded from the existing literature regarding the milestones that pre-schoolers have to accomplish around their age, as mentioned in section 2.4 in Chapter 2.

The meaning of a supportive environment extended to the usability, reliability and safety of DATU-centric toys. For usability, the specialists needed toys that are challenging enough for pre-schoolers but not too hard to use. The need for reliability reflected their intention of keeping the toys usable over the long term and heavy usage in their clinical practices. For safety, the specialists had similar standpoints with parents, as they both mentioned physical, content, and internet safety.

Converging the specialists' viewpoint towards pre-schoolers' technology use, DATU-centric toys have to deliver huge values to their perceived supportive environment. The specialists recognized that traditional toys are sufficient for supporting child development. The negative impact of existing technology devices used by pre-schoolers outweighed the advantages. This insight resonates with the existing finding that child development specialists are not necessarily sure about how to support pre-schooler development with technology-augmented toys (Ihamäki & Heljakka, 2018). Some specialists further addressed that lack of screen time management can impact the supportive environment. However, most of these viewpoints were raised from their perception of existing electronic devices, which may change if novel DATU-centric toys are implemented in creating a supportive environment for pre-schoolers. Some of the specialists also mentioned examples of novel toys that use technology to enhance the play experience and sensory stimulation. These findings further confirm the possibility of creating DATU-centric toys that can satisfy the specialists' needs to an extent.

Both parents and child development specialists wish pre-schoolers to grow healthy. However, these two groups of stakeholders care for pre-schoolers from different angles. The specialists recognized the necessary discomforts in learning. They support pre-schoolers' growth by carefully managing, guiding, and assessing the play activities. The parents recognized the child development requirements and some of them realized the necessary challenges for pre-schoolers. However, the parents also wished to encourage their children's growth in other fields that they find important. Furthermore, the parents perceived play as a relieving and relationship-reinforcing activity. This insight resonates with the parent and child demographical-related factors which are listed as the second and third important variables in the parent toy selection decision model (Al Kurdi, 2017). Therefore, they recognized DATU-centric toys as a potentially less stressful way to support the growth of their children. As the needs between specialists and parents were not mutually exclusive, designers should attempt to seek

balance in satisfying both groups of stakeholders in designing DATU-centric toys. Hence, the findings in this research were further interpreted for creating guidelines for designers.

7.3 Limitations of the study

There are limitations affecting the validity and generalizability of the research outcomes. The set of design guidelines was finalised without testing in a real-world project. Without testing the design guidelines in actual projects, it is hard to tell how reliable they are when implemented. However, testing a set of design guidelines can be a very long and complicated process, which was not feasible to be done within the limited timeframe in this MPhil study. As this study constructs knowledge based on individual viewpoints, it is nearly impossible to replicate the same result even with the same methods and participants. The low replicability is caused by the fact that viewpoints can be affected by many factors such as differences in experience. For example, a novice designer who experienced the research activities and learned about the finalised guidelines, cannot be identified as a novice designer anymore. Therefore, the validity of the research outcomes is limited.

The generalisability of the research outcomes is affected by the scale of the study. The study was conducted with ten participants. The sample size was acceptable at the beginning of the research as the study focus on the qualitative data. However, dropout was experienced which may affect the research outcomes. The dropout occurred significantly in the final phase was caused by the change of participants' availability over 10 months of data collection process in this study. The change of availability was led by personal reasons related to COVID-19 and career changes. For ethical research conduct, details of these reasons cannot be disclosed. As this longitudinal study adopted an iterative framework, recruiting new participants for producing new data based on the creations of different individuals would impact the validity of this study. To avoid incorrect interpretations and misunderstandings, it was not advisable to recruit new participants.

7.4 Industrial implications

The research outcomes have a practical and positive impact on the toy design industry. The set of design guidelines advocates the importance and possibility of considering both parents' and child developmental needs in toy design. The document supports the philosophical standpoint that toy design should be initiated from stakeholders' needs, especially developmental needs, instead of solely marketing needs. The documented practice and findings in this research also encourage novice designers to pioneer new ideas in the toy industry and help the training of toy designers provided by

toy makers. As technology misuse in early childhood can be devastating to child development, the set of design guidelines can also inspire policymakers to create ethical directives for toy makers to follow. Ultimately, the findings in this research contributed to nurturing and sustaining the toy industry from a humanitarian standpoint.

7.5 Academic implications

The research outcomes have academic implications in the field of design thinking, design-based research and design for children. The practice of conducting a design thinking process within a design-based research framework pioneered the possibilities of applying them in future studies. The findings show that it is feasible to utilise the design thinking process in academic research.

The academic implementation of a framework composite of the design-based research framework and design thinking process is new and rare, yet it can blur the boundaries between researchers and participants to facilitate innovation through collaboration (Henderson et al., 2022). As the research findings prove that the combination of design thinking and design-based research framework can be used to create solutions and construct knowledge, it reinforces the effectiveness of this methodology. The combination of design-based research framework and design thinking process resonates with the existing literature which states that researchers should shift from the role of designers to researchers along design-based research (Plomp, 2013, p.30). This implication also resonates with the findings from a recent study which also adopted Design-based research framework and design thinking process (Henderson et al., 2022). The frameworks used in this study and in Henderson et al.'s study, introduced the need and effective way for designers to find worth solving problems. This study also resonates with the design principles created by Henderson et al. as this study encourages designers to be learners and empathise with stakeholders. While the term designer is recognized as toy designer in this study, it can also represents educators which are designers of learning (Henderson et al., 2022). The framework used in this study thus further promote the benefits and rationale for professional learning with design thinking methods (Henderson et al., 2022). As this study was able to contribute knowledge under the pressure of being affected by various factors, the flexibility of such a research framework is also proved to be advisable.

The parents' and child development specialists' needs found in this research contribute knowledge to the field of developmentally appropriate technology use (DATU) in early childhood, and to human-centered design as a broader research field. The contributed knowledge can be applied in studies

about designing play activities and environment for parents and children. The needs can be further applied as reference points for studying the effectiveness of child-related inventions designed with human-centered approaches. These inventions include but are not limited to children's products, educational curricula, and play space design.

In addition, the positive feedback on the research outcomes shows that toy design is a field that is worth investigating. To conclude, the findings expand a potential field for future research in DATU and encourage the application of the design thinking process, and design-based research framework in academic research.

7.6 Recommendations for future work

Future work of a longer study involving more stakeholders such as toymakers and pre-schoolers is needed to further improve and support the validity and effectiveness of these findings. As the guidelines were finalised with the input of three individuals, they need further refinement, testing, and validation. Toymakers can contribute with their industrial experience to improving the guidelines. The further improved guidelines can be implemented into design projects. The result of these design projects can be compared with those without the improved guidelines. The comparison can be made upon the toymaker's evaluation of designers' performance but can also be the observation of pre-schooler interactions with the prototypes. A study adding these two groups of stakeholders can provide more solid and all-rounded findings in this research field.

Another direction of future work is to study the possibilities of implementing technology to augment toys across different age ranges. The potential of using technology to make a toy suitable for a wider age range was noticeable in the findings. A project aiming to explore this potential can help increase the sustainability of toys. The findings from such a project can impact the industry where traditional toys are designed to last for a short period of childhood.

7.7 Conclusion

Technology use in early childhood sparks the potential for innovation in play. However, the research is sparse on augmenting pre-schooler toys in a developmentally appropriate way. Considering the potential impact caused by the misuse of technology, more effort in advocating and helping the creation of DATU pre-schooler toys was needed. In contributing to filling this research gap, this thesis

has demonstrated a set of guidelines to help novice designers in navigating their research and development (R&D) process of DATU pre-schooler toys.

The set of guidelines provided six perspectives outlining parents' and specialists' concerns. The six perspectives are Form of play, Values from play, Imagination, Interactions, Toy attributes, and Technology influence. These concerns can be taken as reference points in toy design projects. Designers who consider these concerns can create results that show more empathy towards parents and pre-schoolers. The set of guidelines further indicates explorable areas and possible conflicts that need to be resolved in toy design projects, gifting a lower cost and lead time in design projects.

Through the journey of forming the guidelines, this study has shown the effectiveness of design thinking in seeking a balance between contrasting viewpoints. Studies involving designers, parents and child development specialists at the same time are rare. The success of handling the complexity in this study acts as a beacon in this research field. The methods and practices used in this research inspire new studies in the exploration of new knowledge for creating toys that bring greater satisfaction.

Finally, the research practice and outcomes support the vision of developing toys from a humanitarian standpoint. This thesis encourages the toymakers and policymakers to take action in protecting pre-schoolers from the aftermath of technology misuse and sustaining the industry. This thesis suggests guidelines that can be followed by designers to create developmentally appropriate technology toys to be used in a healthy environment involving children, parents, and caretakers while supporting the toy industry.

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Appendices

Invitation to designers

INFORMATION SHEET

PROJECT TITLE: A guide to support design of electronic toys for pre-schoolers aged 4-5 years old

You are invited to take part in a research project, gathering the opinions of parents, paediatricians and designers and then use that information to develop guidelines for the design of electronic toys for pre-schoolers. You are invited because you are a fluent English-speaking adult and:

1. **Having experience in product or interaction design**
2. **Feeling comfortable about hosting a discussion**
3. **Not having toy experience in designing children products**

The study is being conducted by KIM TO TSE and will contribute to the degree project in Master of Philosophy (Information Technology) at James Cook University.

If you agree to be involved in the study, you will be invited to join two discussion group sessions and two workshop sessions (4 in total). These sessions, with your consent, will be audio-taped.

Research activity	Activity Description	Duration	Participants & Location
Orientation Workshop	The research team will give a presentation about design thinking, details of the study and upcoming activities. Participants will then brainstorm some questions to ask during next activity (Discussion group A).	1 hour 50 minutes	Designers (JCU Townsville campus and/or Zoom)
Discussion Group A	In small groups (composed of a designer, a paediatrician and a parent) participants will share views and opinions regarding the use of and design of electronic toys for pre-schoolers with the assistance of the research team.	45 mins	Designers, Paediatricians and Parents (JCU Townsville campus and/or Zoom)
Workshop A	Designers will work together with the research team to interpret the gathered data from the previous discussion into design challenges. Activities will include brainstorming, sketching and collating information from Discussion Group A. Information from this workshop will assist	3 hours	Designers (JCU Townsville campus)

	the researcher in developing some preliminary guidelines which will be discussed in more detail in the following workshop		
Workshop B	**The researcher team will present a set of preliminary guidelines and request feedback and suggestions/feedback from the group regarding solutions for challenges designers face in developing plans for electronic toys.**	**2 hours 15 minutes**	**Designers** **(JCU Townsville campus)**
Discussion Group B	**The research team will give a presentation about the final guidelines that have been developed and lead a discussion around designing toys. As part of the larger group, you will be asked to comment and/or raise questions upon on findings/outcomes of the study**	**40mins**	**Designers, Paediatricians and Parents** **(JCU Townsville campus and/or Zoom)**

Taking part in this study is completely voluntary and you can stop taking part in the study at any time without explanation or prejudice. Collected data will be identified and coded. We will greatly appreciate your contribution and all contributed knowledge will aid in developing a set of guidelines for designing toys.

If you know of others that might be interested in this study, please pass along this information sheet to them so they may contact me to volunteer for the study.

Your responses and contact details will be held as confidential. The data from the study will be used in research publications and reports. You will not be identified in any way in these publications.

If you have any questions about the study, please contact Kim To Tse, Dr Dianna Hardy or Dr Jason Holdsworth.

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If you have any concerns regarding the ethical conduct of the study, please contact:

Human Ethics, Research Office

James Cook University, Townsville, Queensland, 4811

Phone: (07) 4781 5011 (ethics@jcu.edu.au)

Invitation to parents of young children

INFORMATION SHEET

PROJECT TITLE: A guide to support design of electronic toys for pre-schoolers aged 4-5 years old

You are invited to take part in a research project, gathering the opinions of parents, paediatricians and designers and then use that information to develop guidelines for the design of electronic toys for pre-schoolers. You are invited because you are a fluent English-speaking adult and:

1. **Having at least one child aged between 4-5 years old in the past five years**
2. **Not feeling negative towards usage of electronic toys**

The study is being conducted by KIM TO TSE and will contribute to the degree project in Master of Philosophy (Information Technology) at James Cook University.

Research activity	Activity Description	Duration	Participants & Location
Orientation Workshop	The research team will give a presentation about the details of the study and upcoming activities. Then participants will form small groups and share their opinions on current electronic toys in the toy market.	1 hour 40 minutes	Child development specialists and Parents (JCU Townsville campus and/or Zoom)
Discussion Group A	In small groups (composed of a designer, a child development specialist and a parent) participants will share views and opinions regarding the use of and design of electronic toys for pre-schoolers with the assistance of the research team.	45 mins	Designers, Child development specialists and Parents (JCU Townsville campus and/or Zoom)
Discussion Group B	The research team will give a presentation about the final guidelines that have been developed and lead a discussion around designing toys. As part of the larger group, you will be asked to comment and/or raise questions upon on findings/outcomes of the study	40 mins	Designers, Child development specialists and Parents (JCU Townsville campus and/or Zoom)

Taking part in this study is completely voluntary and you can stop taking part in the study at any time without explanation or prejudice. Collected data will be identified and coded. We will greatly appreciate your contribution and all contributed knowledge will aid in developing a set of guidelines for designing toys.

If you know of others that might be interested in this study, please pass on this information sheet to them so they may contact me to volunteer for the study.

Your responses and contact details will be held as confidential. The data from the study will be used in research publications and reports. You will not be identified in any way in these publications.

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Invitation to child development specialists

INFORMATION SHEET

PROJECT TITLE: A guide to support design of electronic toys for pre-schoolers aged 4-5 years old

You are invited to take part in a research project, gathering the opinions of parents, child development specialists and designers and then use that information to develop guidelines for the design of electronic toys for pre-schoolers. You are invited because you are a fluent English-speaking adult and have Postgraduate qualifications in Paediatrics

The study is being conducted by KIM TO TSE and will contribute to the degree project in Master of Philosophy (Information Technology) at James Cook University.

Research activity	Activity Description	Duration	Participants & Location
Discussion Group A	In small groups (composed of a designer, a child development specialists and a parent) participants will share views and opinions regarding the use of and design of electronic toys for toddlers with the assistance of the research team.	30-45mins	Designers, Child development specialists and Parents (JCU Townsville campus)
Discussion Group B	The research team will give a presentation about the final guidelines that have been developed and lead a discussion around designing toys. As part of the larger group, you will be asked to comment and/or raise questions upon on findings/outcomes of the study	30-45mins	Designers, Child development specialists and Parents (JCU Townsville campus and/or Zoom)

Taking part in this study is completely voluntary and you can stop taking part in the study at any time without explanation or prejudice. Collected data will be identified and coded. We will greatly appreciate your contribution and all contributed knowledge will aid in developing a set of guidelines for designing toys.

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The preliminary guidelines

Introduction

Designers should take the guidelines to construct their own design projects including three fundamental stages: Understanding Stakeholders, Defining Problems and Creating Solutions. The stakeholders in this document generally refer to parents, and child development specialists.

Understanding stakeholders

There are six perspectives for the journey of understanding the needs of parents and children development specialists. Designers should interview their stakeholders to understand their needs from these perspectives and create their own proto-personas.

- Form of play
- Values from play
- Imagination
- Interactions
- Toy attributes
- Technology Influence

Considerations from six perspectives

The following six perspectives demonstrate the directions and reference points for designers to study their stakeholders.

- Form of play
  - Play should be interesting, relieving, and understandable to children
  - Play should have a balanced use of technology as interactions & stimulations from the physical real-world are critical to children development
- Values from play
  - Values should be based on the developmental needs of pre-schoolers including motor skills, cognitive skills, sensory skills, daily living skills and socio-emotional skills
  - Educational values such as learning language and culture should be recognised as additional values
- Imagination
  - Use of imagination is essential for developing creativity
  - Imaginations in play encourage spontaneous gain of skills
  - Imagination continuously entices children to go through repeated actions
  - Increase the sustainability of the toys by lifting the replay value
- Interactions
  - Social interactions are necessary in socio-emotional development
  - Social interactions can enhance relationships
  - Play experience should be interesting to children and adults
  - Context of interactions in play should be appropriate
- Toy attributes
  - Toys need to be safe, reliable, usable, beneficial, and fun for children

    - Stakeholders' judgements on price are made upon the performance of the above-mentioned factors
- Technology Influence
    - Technology is appealing to parents and children, but child development specialists have concerns about the addictive screen time
    - Conflicts between two groups of stakeholders may be solvable by giving alternative methods for augmenting toys with technology without screens.

Defining problems

- Create some well-defined and clear How-Might-We (HMW)
    - Defined in a way that guides solving problems with toys
    - Involvement of technology should not be included
    - Consider defining sub-questions for various toy requirements
    - Use feedback from multiple parties to revise

Examples for guiding questions

- Defining HMW for play
    - One type of play should be defined on each toy
    - Utilize understanding in form of play, values from play, imagination, and interactions
    - Primarily consider the needs related to children development
- Defining HMW for the theme
    - Clarify what sensory experience the toy is going to bring to children
    - Aim at jump-start brainstorming to satisfy the emotional needs

Creating solutions

- Ideating, prototyping, testing, and iteratively revising the solution are essential in design thinking framework
- Constantly checking design outcomes with stakeholders
- Utilize the understanding of toys' attributes and technology influence

Ideating stage

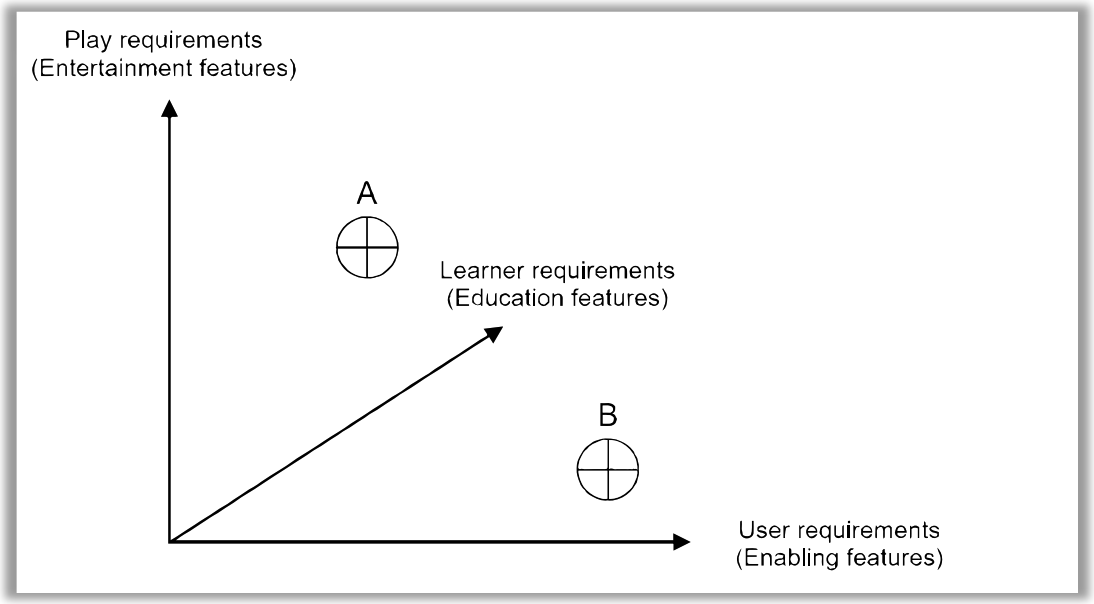
- Use defined HMW questions for hosting brainstorm activities like Crazy Eights
- Converge ideas by voting
- Share and comment among the design team
- Six Thinking Hats can be done independently

Prototyping and Testing Stage

- Depending on the stages of the design project, guiding questions and ideas, varied prototyping methods can be used, for example:

- Early Prototyping: detailed storyboards visualising problem, solution, and benefit
- Prototyping for Sub-HMW questions: Wizard of Oz, mood boards
- Late Prototyping: 3D renderings, playable tactile prototypes

- Consideration of safety is necessary (AS/NZS 8124 series of Safety Standards)
- Co-working on observations of children's play would be more preferred than interviews
- Utilize understandings in children behaviour and plot them in the Player, Learner and User Model:



- Have the stakeholder review the position of the toy in the PLU model
- Designers can use technology to enhance entertainment and enabling features
- Technology may still be applicable for education feature in toys targeting multiple age ranges

Group discussion session guide

1. Talk about what is design
    A. ask what you know or think about design, stating that everyone is designer
2. how their contribution going into(guidelines)
3. Tell them to be yourself, it is not about how smart you are, or how good at a parent you are. It is only about what is your opinion. No right or wrong answer when we are asking for opinions.
4. Questions for group sharing of choosing toys
    A. Tell me about the experience last time you brought or introduce a toy for a child
    B. Why did you make that decision?
    C. Did the kid enjoy playing it?
    D. What else they got from somebody else?
    E. How would you play with your 4–5 years old kid?
    F. Tell me what you think about giving smartphones/tablets to children.
    G. Have you seen something like this before?
    H. What kind of smart toys have you seen?
    I. Do you have any smart toys for kids?
    J. Talk about Tablet games?

Interview Questions Guide

Interactions/behaviour:

How would you play electronic toys with your kids?

How would you expect your kids to play with other kids?

What and how do you expect your kids to explore the world other than toy?

How to help children to make eye contact with others?

How many toys do your kids have?

How much time do your kids play with their toys?

What kind of interactions with toys you would expect to help child development? (Physical/emotion/social…? How?)

Have you seen your kids misusing their toys? How?

Do you think your kids would develop emotional attachments with their toys?

Safety/privacy:

Do you think supervision is necessary during play?

How do you feel about toy safety in electronic toys?

How much screen time is appropriate? Why?

Would you buy toys that can connect to the internet? Why?

Learning:

What do you expect your kids to learn when they are playing with toys?

Can you tell me some examples of hand-eye-coordination associated with toys for 4-5 years old?

What do you think about learning a language with toys?

Do think toys can help kids to develop their imagination? How?

What is the difference between learning from toys and from materials in daily life?

Toy Features:

What features you don't like about electronic toys/traditional toys? (sound?)

Why are traditional toys better than electronic toys?

What toys attract the attention of your kids? For how long they are attracted?

What are the potential influences from toys that worry you? (images/text/emojis…)

Can you give me some examples of toys that can link to real-life experiences?

How much would you spend buying toys?

What toys do you think can enhance the relationship with your kids?

What toys can help learning?

Workshop Outline

Event	Outline
Workshop A	Give a brief presentation about the defining and ideating stage in design thinking process. The group will construct two proto-personas to summarize what we have found from parents and children development specialists. This will be done with references of individual empathy maps.
Workshop B	Each designer does individual brainstorm on creating HMW questions from what you have found interesting in proto-personas, and then the group will discuss and try to enhance the ideas. Two HMW questions will be selected with the dot-voting method. The group will then use SCAMPER targeted brainstorm to generate some ideas to solve the problem. We will use Miro.com to sketch our ideas for this activity.
Workshop C	Go through the prototype and testing stage in the design thinking process. We will create some low-resolution “paper-prototypes” with Miro.com. We will have someone come and ask some questions for “testing” the prototypes. We will have a focus group session afterwards to share our difficulties during the design process.