Application of Modularity Principles in Designing of Functional Regenerating Open-ended Toys Alongside with Child Development

by

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Abstract

The toy industry is massive. This benefits children a lot with varieties of creations sprouting every year. This hurts the environment due to their poor quality and usability. As an industrial designer, designing the product that serves for a longer time is an efficient way to contribute to our environment and our future.

This thesis is aiming at teaching designers an approach for designing an open-ended toy which can grow with children. With children's development, their needs are rapidly changing. This is because their abilities are developing dramatically. So studying children and play development is becoming significantly vital for delivering a successful outcome at the end of the research. Different children development theories will be included in the literature review. Open-ended toy provides children more varieties of playing. Controlling the openness is essential in the development of children and the toys. Modularity principles will also be studied to assist the goal creating of growable toys.

Acknowledgements

Finally, this is the day for me to finish my thesis. Although the entire thesis-developing process was not too long, I feel like I did walk through a pretty long journey from the start to this end. Struggling always happened but having this experience has made me grown up.

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Chapter 1 Introduction

1.1 Problem Statement

With today's fast-growing technology and economy, children's life is also becoming full of variety, and a main reason can be their toys. According to a report from The NPD Group (National Purchase Diary Panel Inc.), global toy sales grew by 1 percent to $20.7 billion in 2017. With such a huge sale number as above, it is impossible to ignore the effects caused by this massive industry. Among the effects, toy waste is an important issue that we need to pay attention to.

Thinking about why the toy waste is hard to deal with, the first reason is the huge purchasing power from parents and relatives. Not only do toy manufactures produce a large number of toy products, but also adults always have the desire to buy more. And the reason of this great desire from one point is coming from the guilty feeling that parents have that they can't spend enough time with their kids (Bohn, 2011). When the parents want to appease this kind of feeling, they may end up by buying more toys for their child. Other reasons can be peer pressure, overloaded holiday gifts and good-behaviors rewards, etc. A research study conducted by Neil Gray of Dream Town Toy revealed that one in two parents admit "wasting hundreds of U.K.

pounds" on toys their children never play with (O'Grady, 2010). So we can see over- purchasing toys is a vital issue in toy sustainability. No buying, no wasting.

The second reason can be the poor quality and recyclability of some toys. "More than 40% of the toys gifted to kids during the holiday season alone are broken by spring. To make matters worse, approximately 90% of toys on the market are made out of plastic" (Szaky, 2015). After the toy is broken, recycling is the only way to make the toy sustainable. At the same time, plastic toys are much harder to be recycled when compared to recyclable plastic bottles due to their material complexity. Firstly, plastic toys typically include other materials such as metal, which can be hard to separate out and becomes prohibitive for recycling centers, states Brent Bell, vice president of recycling at Waste Management, a company that provides solutions to business and residences in North America (Goldberg, 2017). Secondly, toys are made with a wide variety of plastics. And different municipalities vary greatly in their ability to accept certain plastics, which makes the toy recycling even harder (Szaky, 2015).

The third reason is the short use time for functional toys. A typical child owns 238 toys in total but parents think they play with just 12 'favorites' on a daily basis making up just five per cent of their toys (O'Grady, 2010). These 226 disfavored toys can be assumed as unbroken toys because parents have no reason to keep the broken toys that their kids don't like.

In addition to toy waste, toy abuse is another significant issue which is already widely spread. As summarized earlier, the causes of toy abuse are also connected to "huge purchasing power" and "short serving time for functional toys". The fact of getting toys too easily may lead

to the difficulty in helping children establish the correct values when they are young. Spoiling is really bad for children's development. In another way, toy abuse can also decrease children's play quality. A study from University of Toledo shows that children who play with 4 toys will have a better play quality compared to children who play with 16 toys. Children's groups with 16 toys will spend more time observing the toys and will result in the children easily getting bored and impatient; children's group with 4 toys will spend more time on discovering the playing potential of each toys and will result in more inspired and creative play. (Philpot, 2014) This result shows also that the good toys need to have the potential and possibility for children to explore. In toy play, "the quality" is much important than "the quantity."

1.2 Need for Study

Regarding the three reasons of the difficulty of toy sustainability introduced above, toy companies, recycling companies, nonprofit associations and social appeals are all fighting against them in their own ways.

The first main direction is focusing on developing green material for manufacturing and packaging. "The LEGO Group dedicates 1 billion DKK and sets up LEGO Sustainable Materials Centre to find and implement new sustainable alternative to current raw materials" (Trangbæk, 2015). The newly launched LEGOs in 2018 have the botanical elements such as leaves, bushes and trees to be made from plant-based plastic, which is their first sustainable manufacturing material approach (Gherasim, 2018). The Green Toys Inc. (n.d.), an eco-friendly toy company, uses milk jugs as the primary raw material to develop their toy products (Figure 1.1). They also

have some other green design strategies such as using soy ink for package printing and using snapping connections in order to eliminate hardware. Because of the entirely green design process, the end-of-life recycling can also be much easier. Some toy companies such as TEGU (Figure 1.2), HAPE and YOXO use wood as their major product material, which can also reduce the product's carbon footprint successfully.

Figure 1. 1 Toys from Green Toys

Figure 1. 2 Toys from TEGU

The second main direction is dealing with the end-of-life toy recycling. One approach is to make recycling non-functional toys. TerraCycle (n.d.) is a recycling company, which takes non-recyclable pre-consumer and post-consumer waste and turns it into a raw material to be used

in new products. They partner with sponsored companies and make consumers could recycle the end-of-life products with the free shipping label. One of TerraCycle's partners is Hasbro Inc., a magnate toy maker in U.S. Hasbro not only provides sponsorship to TerraCycle for collecting, but also helps them to overcome the challenges that pop up during the recycling process (Workman, 2018).

And the other approach to recycling end-of-life toys approach is to give functional toys a second chance to serve as toys. This approach is widely used by some nonprofit associations and second-hand stores. "Toy library offer a place for families and individuals to donate their gently used toys so that they don't end up in landfill", said Judy Iacuzzi, executive director of the USA Toy Library Association (Szczepanski, 2017). Toy libraries (Figure 1.3) were initially founded to solve the toy shortage issue during the time of the Great Depression. The low-income families can have their kids borrow the toys freely from the toy library. Currently, the toy library has changed its role into a sustainable toy association. Goodwill, a nonprofit organization in U.S., also has donation options for people who want their toys to have a second life. Clean and functional toys will be accepted by Goodwill and resold in stores and online.

Figure 1. 3 Toy Libraries

In my research, I found that most of the sustainable toy approaches are either working on making “greener” manufacturing and packaging materials or developing end-of-life recycling, while companies seldom are paying attention to the in-use sustainability, which means extending toys’ lifespan. Creating an emotional connection is one approach. If designers could successfully design and create the emotional bond between consumer and product, the product may increase its lifespan because rather than a tool, product may be treated as a good buddy or a family member to the consumer (Schifferstein, Hendrik, Ruth & Paul, 2004). Exploring the potential of one toy by using modular thinking is another way. The exploration can be maintaining the non-functional parts, updating the current play patterns and extending the play versatilities. Moreover, not like adults, kids are rapidly growing, either physically or mentally. It’s necessary to convert children development factors to the modular thinking. In conclusion, using modular thinking to develop toys is essential in toy sustainability.

1.3 Objective of Study

- To study the concept of toy and play and their benefits
- To define and study open-ended toys
- To study the theories of children and play development
- To define and study modular design
- To determine the relationship between play, open-ended toy, children development and modularity

- To develop an approach of using modular thinking to develop open-ended toys

1.4 Definition of Terms

Function- The action for which a person or thing is specially fitted or used or for which a thing exists ("Function," n.d.).

Modular- Employing or involving a module or modules as the basis of design or construction ("Modular," n.d.).

Play- Engage in activity for enjoyment and recreation rather than a serious or practical purpose ("Play," n.d.).

Sustainable- Of, relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged ("Sustainable," n.d.).

Toy- Something for a child to play with. Toy is something that can be toyed with ("Toy," n.d.).

1.5 Assumptions of Study

It is assumed that all the research, approaches, methods and data I found are correct.

It is assumed that people do care about the environmental issue of toy waste.

It is assumed that the issue of toy waste can be relieved by product design process.

It is assumed that toy waste during the in-use stage should have some causes, which could be discovered and analyzed.

It is assumed that there are no other products that can replace the function and status that toys have.

1.6 Scope and Limitations

Though the research is to study the sustainability of toy design, it will focus on developing the strategies around modular thinking during the in-use stage. Some other important sustainable aspects in other stages will not be developed in the approach, such as raw material selecting and processing, packaging, manufacturing methods, material recycling, and etc. It is because seldom have sustainable approaches been achieved for the in-use stage. This will be further developed in the Literature Review.

Also, only open-ended toys will be discussed since close-ended toys only serve one-time play or one-purpose play. Children's furniture, playground, physical game play and baby toy design will not be included in the design approach. The concluded open-ended toy types will be discussed and defined in the Literature Review. The study focuses on the study of children's toys. Toys designed for adults will not be considered.

1.7 Procedures and Methodology

Procedure 1: Study the concepts of toy, play and their benefits and define open-ended toy.

- Studying online research, dictionaries, articles and library resources
- Analyzing existing products

Procedure 2: Study the theories of play and children's development and summarize.

- Studying online researches, dictionaries, articles and library resources
- Sort and analyze research

Procedure 3: Study current sustainable design strategies and define the role of modular thinking.

- Studying online research, dictionaries, articles and library resources
- Sort and analyze researches.

Procedure 4: Study cases of current modular toy design approaches and extract the strategies.

- Collect cases
- Analyzing sustainable cases
- Extracting sustainable strategies

Procedure 5: Summarize the relationship between modular thinking, open-ended toys and children's development needs and build up the frame of the design flow.

- Studying online research, dictionaries, articles and library resources
- Analyze and illustrate relationships

Procedure 6: Develop the design flow of open-ended toy design by using modular thinking.

Procedure 7: Apply the approach into a real product design process.

1.8 Anticipated Outcomes

The primary outcome is to help designers to design open-ended sustainable toys via modular thinking. The toys designed by this approach can serve a wider age group of kids with a longer lifespan comparing to the existing toys. Then the toy waste will be reduced.

Chapter 2 Literature Review

2.1 Role of Play

The first term that needs to be talked about is toy. It's really interesting to notice that all the definition of the word "toy" is highly related to another term, "play". According to the explanation in Merriam-Webster, a toy is "something for a child to play with" ("Toy", n.d.). Such explaining can be understood as toy serves as a tool for the playing experience. Other opinions also indicate the strong connection between toy and play. An example can be the comments from Newson and Newson (1979): "Play comes first; toys merely follow" (p. 12). As the glimpse of different ideas shown, the idea of toy seems dominated by play. So, in order to dig into the research of "toy," understanding "play" should be the very first step.

2.1.1 Play Theories

2.1.1.1 Classical Theories of Play

Several classic theories explain the phenomenon of play. Getting to know the history of play research is a great starting point to understand the relationship between play and toys.

Surplus energy theory was pointed out by Friedrich Schiller, an eighteenth-century German poet, and Herbert Spencer, a nineteenth century British philosopher. The theory presented that every creature in this world generates a certain amount of energy for meeting the

need of survival. The leftover energy after the need consumed is called surplus energy. Play is the medium for creatures to release this energy and the pressure behind it through purposeless behaviors (Groos, 1898).

Recreation theory, which holds a direct opposite opinion against surplus energy theory, was proposed by German poet Moritz Lazarus. The theory states that working could use up all the energy and cause an energy deficit. The only way to regenerate and recover the energy is to do something against working. Play is the ideal way to solve the energy deficit (Mellou, 1994).

Practice theory was stated by philosopher Karl Groos. He believed that play offers young creatures a safer way to practice and perfect the skills that they need for future adult life (Mellou, 1994). The purpose of toys has practically always been educational. To practice future adult roles by imitating them in play was regarded as an exclusive pastime in the old days (Goldstein, 1994).

All of these classical theories of play have either serious weaknesses or important meanings. The surplus energy theory fails to explain why children continue to play when drained. The recreation theory cannot explain why adults work more but play less when compared to children (Johnson, Christie, & Yawkey, 1987). And the practice theory fails to explain most of the playing behaviors in adulthood. However, they're still vital for the play theory development. First, they give the later theorists a historical perspective to adult attitudes toward play. The classic theories are debating about the importance of play, as the surplus energy theory holds that play is purposeless and nonproductive behavior while the practice theory states that play is vital for creatures' survival. Second, some theories are still rooted in people's mind

such as surplus energy theory. Third, the modern theories of play are developed based on the classical theories at some point.

2.1.1.2 Modern Theories of Play

Modern theories of play not only focus on figuring out why the play exists, but also trying to find the connection between play and children development.

These theories include the cognitive theory of play from Piaget, the cognitive development theory from Vygotsky, the psychoanalytic theory of play from Freud, the stages of psychosocial development theory from Erikson (an extension theory from Freud's), the arousal modulation theory from Berlyne, the theory of play from Bateson, and others. Table 2.1 briefly shows the important statements that these theories developed. The details of these theories will be discussed later in the chapter.

Theory	Developer	Statement
Cognitive	Jean Piaget	Children construct an understanding of the world. The continuous experience discrepancies make them grow.
Sociocultural	Lev Vygotsky	The role of culture, social, language and adult are emphasized in cognitive development.
Psychoanalytic	Sigmund Freud	Play helps a lot in children emotional development. It relieves children when dealing with the negative feelings.

Arousal Modulation	Daniel Berlyne	Play is treated as a stimulus-seeking activity which can keep arousal at an optimal level.
Play & Fantasy	Gregory Bateson	Play promotes children to understand and master multiple levels of meanings.

Table 2. 1 Modern Theories of Play

2.1.2 Definitions of Play

"Play has been loosely defined to include activities in which children engage for the sake of amusement, passing time, being part of a group, or learning and practicing skills" (Mergen, 1982, p. 103). The statement of play from Mergen has two important messages. First of all, play appears almost in every aspect of children's daily life. Secondly, this definition is loose, whether it's because the explanation is not integrated enough, or some other debates were made when talking about this term. Some scholars have even considered the term of play as undefinable (Schlosberg, 1947).

One reason why play is complex to explain is that play can be seen as a paradox at some point. Play is a "paradox of what is essential and inconsequential", "serious and the nonserious" (Henricks, 2015, p. 19). One can say that play is a serious activity because it offers children's first way of learning and developing; another one can say that play is not serious at all because of its aimless and spontaneous features. One can say that play can bring unexpected result because play itself is an exploration, an adventure, an experiment or an attempt; another one can say that

play's result is expected because it's been justified that play has a significant role in children's healthy development (Kepler, 1952).

Also, play is hard to define purely through the behaviors with no context. An easily-understood example can be 'chase and run'. If people only see or hear the phrase 'chase and run', they may imagine it's a police chasing a criminal, a father chasing his naughty son or a boy chasing his best friend. However, if this behavior is described or seen in a specified context, it's much easier to distinguish if this activity is expressing guilt and anger or happiness and friendliness through their sounds, face expression, detail behaviors and etc. As Catherine (1990) stated, play has certain systematic relations to what is not play. Contrast provides the opportunity to identify if it's play or not. We can only speak of play when we can contrast it with other orientations; we can only identify playful behavior when the actor can engage in corresponding but contrasting non-playful behaviors. Jumping, throwing a stone, even asking a question, or imitating another person's speech can be performed as play but can also be performed in non-play fashion and with non-playful intent.

> Henricks (2015) made two statements for the related content that we discussed earlier:
>
> First, there is substantial variety in the activities that people call play. Play objects can include all manner of psychological, bodily, environmental, social, and cultural elements. The settings of play activities and the roles of people in those settings may also vary dramatically. Second, this diversity of expression and interpretation should be seen as the empirical basis for discovering what is common to all forms of play. (p. 22)

2.1.3 Characteristics of Play

Though play is hard to describe in one single sentence, summarizing the characteristics that play has is beneficial to fully comprehend play.

Virtual: When Goldstein (1994) made the comment on pretend play, he wrote, two opposed feelings are mixed in this type of play: "security in being oneself and excitement in acting contrary to oneself" (p. 59). Play is not real. Adults know it. Children also know it. These unreal imaginative behaviors are all coming from the real-world experiences. One can be meaning substitution. Johnson, Christie and Yawkey (1987) stated that within the play frame, internal reality is able to take over the external reality. The usual meanings will be ignored and the new meanings will be substituted. Another can be object representation. In meaning substitution, a cylinder block can be whatever that child wants: a column from a Greek palace, a flashlight for her little doll or even a skyscraper in New York City. "Anything is a toy if I choose to describe what I am doing with it as play" (Newson & Newson, 1979, p. 13). In contrast, in object representative, toy train is the high-speed railway train, toy car is the Porsche 911. Although there are no detail features that look the same as a child can see in the real life, child can use images in a flexible fashion, and this ability to approximate rather than to try to represent reality in a fully accurate, videotape-like fashion is an important aspect of play (Goldstein, 1994).

Free and Self-ruled: Fundamentally, play seems to be a partly random and infinitely flexible activity which affords an opportunity for the extension and reorientation of both mind

and spirit. The child who is engaged in true play may establish some rituals and behaviors. And she can always jump out of them at any time because it is herself that define the rituals (Newson & Newson, 1979). Making rules by themselves allows children able to expand their imagination as widely as possible. Mergen (1982) also said that "play with toys reflects the middle-class ideals of achievement, flexibility, and rule-making rather than rule following" (p. 119).

Positive: Play is pleasurable, enjoyable. Even when not actually accompanied by signs of mirth, it is still positively valued by the player (Catherine, 1990). The positive characteristic of play can also help children to control their emotions, especially the negative feeling. Play permits children to display, control and manage their feelings. This benefit will help them to cope with different feelings as well as emotions throughout life. This also means play can help children to learn the ways to "safely" express their feelings and to control and manage feelings of hostility and aggression (Butler, Gotts & Quisenberry, 1978). According to Goldstein (1994), the negative emotions such as terror, fear, anger, or sadness appear when children experience an unfamiliar suddenness which break a long period and cause an unbearable incongruity. The positive emotions appear when children successfully match the new information to their well-established cognition. During imaginative play the child, by reducing the unimportant details of the external environment to bearable size, decreases the large incongruities between what he already knows and the massive complexity of the external environment, the adult world. Thus, play can effectively assist children to learn to control the negative emotions and create the positive emotions.

Paradoxical: As the earlier paragraph presented, play is paradoxical. In addition to the "chase and run" type of paradoxical behaviors which already have been discussed, the "bad play" should also be considered. Bad play is the play that does not allow for the socialization process to take place in positive ways for all children involved (Scarlett et al, 2005). Peer victimization can be treated as one of the bad plays. The behaviors are perceived by one child as play, and by the other child as aggression. The bad play sometimes occurs with little signal. A playful soccer game play may turn into a fight because of some unnoticeable subtle misunderstanding.

Developable: Play can be defined by the behaviors as a developmental design that are prevalent at particular ages. In addition to defining play by what a child does, it can be shown how different play activities help a child develop cognitively, physically, and socially (Butler et al., 1978). It has two meanings, one is that play is great for children development at different stages; the other is that the play which is able to serve the developing children is developable for itself. From another stand point, according to Newson & Newson (1979), "play contains in it some elements of past experience, and every child brings to her play the uniqueness of her own personality" (p. 12). Because of the elements from the past experience, play is able to grow and develop with the child. In the following, the development stages of play will be analyzed.

2.2 The Development of Play and Children

2.2.1 Modern Theories in Play and Children Development

Table 2.1 has briefly shown some ideas of the modern theories in play and child development. This part will have some deeper analysis and comparison of each theory. Only the systematized theories with development perspectives will be discussed in this part. More theories will be studied and categorized in the later paragraphs.

2.2.1.1 Piaget's Theory of Cognitive Development

Piaget's theory of cognitive development is a comprehensive theory about the nature and development of human intelligence. The theory was created by the Swiss developmental psychologist Jean Piaget (1896-1980). The theory deals how humans absorb and acquire new knowledge, reconstruct the existing cognitive scheme and use that for the further exploration through play (Piaget, 1962).

Because the theory also discusses how the initial cognition is formed and shaped, it provides very important theoretical support in the child development field. There are three important aspects stated: the first one is the concept of assimilation and accommodation, the second one is the cognitive development stages and the third one is the stages of play corresponding to cognitive development.

2.2.1.1.1 The Concept of Assimilation and Accommodation

According to Piaget's theory, the child merges new experiences or environmental information into his or her existing cognitive structure through assimilation. Accommodation is

the creation of new structures made necessary by newly assimilated experiences or information. Piaget classified these two distinctive behavioral tendencies as play and imitation. He defined play as a continuation of assimilation and imitation as a continuation of accommodation (Butler et al., 1978).

In other words, when dealing with the new external information, there will be two choices of different situations, either assimilation or accommodation. Assimilation is the process of the child trying to absorb the new information into the existing cognitive structure. It's updating. The updating process is play. When the new information is too hard to absorb in the existing structure, which means the conflicts and differences overload existing cognitive structure, accommodation appears. Accommodation is the process of forming new cognitive structure. The forming process is imitation. That's the reason why Piaget treated play as an imbalanced state in which assimilation dominates over accommodation (Johnson et al., 1987).

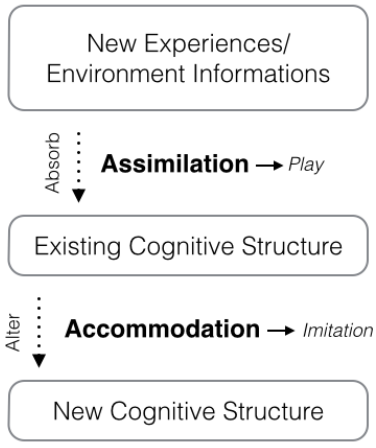

Figure 2. 1 Illustrations of Assimilation & Accommodation

2.2.1.1.2 The Cognitive Development Stages

Sensorimotor Stage: The sensorimotor stage is the first of the four stages that Piaget stated in cognitive development. It starts from birth to the acquisition of language.

> The word sensory emphasizes the roles of (a) sucking and mouthing, (b) making sounds and listening, and (c) gazing at and following moving objects visually, including one's own hands and feet. The word motor emphasizes those simple movements of infancy which result in (a) control of grasping and handling objects, (b) physical mobility from sitting up and eventual walking and running, (c) production of speech sounds and the formation of words, and (d) exploration and knowledge of one's own body. (Butler et al., 1978, p. 27)

Infants acquire the knowledge from the external world by coordinating experiences (such as vision and hearing) with physical interactions with objects (such as grabbing, sucking, and kicking). During this stage, one of the biggest accomplishments that a child gains is object permanence, which means the understanding that objects will exist even though he or she don't see or hear them. By the end of this stage, the child will be able to differentiate him or herself with the external object permanently (Butler et al., 1978).

Pre-operational Stage: The second stage starts when child begins to learn to speak at the age of 2 and ends at the age of 7. During this stage, Piaget (1962) indicated that children are able to shape stable concepts. However, they still couldn't understand the actual logic or operate information mentally. Children remain egocentric in this stage, meaning that they have difficulty understanding the viewpoint of others.

There are two sub-stages in pre-operational stage: the symbolic function sub-stage (age 2 to 4) and the intuitive thought sub-stage (age 4 to 7). The symbolic function sub-stage is when

children are able to perceive the objects in their mind without having the object in front of them. The intuitive thought sub-stage is when children start to ask ‘why’. It’s the stage that children want to understand everything (Piaget, 1962).

Concrete Operational Stage: The third stage occurs between the ages of 7 and 11 and is characterized by the appropriate use of logic. Children start solving problems in a more logical fashion. Because it’s still too early for them to use hypothetical thinking, they can only solve problems that apply to concrete events and objects. Another way to conclude this is that children could understand inductive logic and couldn’t comprehend the deductive logic. The inductive logic is the ability to draw inferences from observations and make a generalization. The deductive logic is the ability to use a generalized principle to predict and calculate the outcome of a specific event.

Formal Operational Stage: The final stage is from adolescence to adulthood, roughly ages 11 to approximately 15-20. During this stage, children are capable of hypothetical and deductive reasoning. They develop the ability to think about abstract concepts. Abstract thought emerges during the formal operational stage. Children are able to consider the possible outcomes and consequences of actions. Metacognition, the capability of ‘thinking about thinking’, enables them to monitor and cognize their thought processes. The problem-solving ability that children gain in this stage means children are able to use trial-and-error to solve problems.

2.2.1.1.3 The Development Stages of Play

Sensorimotor or Practice Play: A child in the sensorimotor period plays by exercising sensory and motor capacities on the environment. According to Piaget, this exercise is the major engine of development in this stage, important for its exploratory aspects (Lillard, 2015). Children may make sounds and play at repeating and imitating them, and eventually they imitate the sounds and actions of others. Their mouths are used frequently both for exploring the world and making sounds. These simple forms of play allow them to practice and learn their motor capabilities and to explore and experience their immediate environment. That's the reason why play at this stage is also called practice play.

Symbolic Play: During the second year of life, there is a transition from the sensorimotor play of the infant to the symbolic play of the pre-operational child. The infant becomes able to evoke images or symbols derived from imitative activities. This enables the infant to engage in beginning pretense or make-believe play (Johnson et al., 1987).

Piaget (1962) indicated that the schemas in sensorimotor play follow one another without any external aim. The objects that children play with only serve their own unique purposes or activities, while in symbolic play, new and unrelated objects will be used to present the purposes that they 'shouldn't be' served. This is the beginning of pretense.

Piaget (1962) also defined three kinds of symbolic play. The first type involves the application of one symbolic scheme to new objects. An example can be the child says 'cry, cry' to her doll and imitates the sound which she already knows from his past experience. The second

type also involves one symbolic scheme, but an object may be substituted for another or the child may act like another person or object. An example can be some imitating behaviors such as shaving like daddy. The third type involves planned combinations of symbolic schemes and a sequence or pattern of behavior. An example can be the child takes a doll for a ride with the stroller and introduces the imagined environments to the doll. During the preschool years, there is an obvious tendency that children are making the symbolic play more and more coherent, which is important for the development of the play in a social context.

Butler, Gotts, and Quisenberry (1978) detailed the symbolic play into productive play and reproductive play. They indicated that the productive play starts from 2 to 4. Children at this stage start to learn the uses of simple or manageable play materials, and use them to satisfy their own purposes. Not like the repeating actions in sensorimotor play, their material using play is more likely to be the play behaviors that most adults recognize. The play at this level is totally for children's own ends rather than accomplishing some goals.

The reproductive play occurs between 4 and 7 years of age. Children progressively use play material and perform actions in more conventional ways, thereby the play result that they accomplish is always related to the physical reality or cultural prescription. And the play of this period is increasingly reproduced from what they understand about both the physical and social realms of experience. Increased productive skills and increased social contact lead to an increase in the child's potential for reproducing the social realities experienced. This happens especially when children use their imaginations to play different social roles.

> Children, even those who play alone, may move on to social role play using dolls, cars, blocks, and other materials. This is called dramatic play. If another child is involved, it is called socio-dramatic (social dramatic) play. They imagine and take turns saying and doing what they believe adults might say and do when carrying out adult roles. Through role playing, children learn to take turns and to limit themselves to what is allowed by a particular role. Once they have learned to take turns and to limit their behavior to a set of rules, they can play simple games with rules. Thus, simple game forms appear which become increasingly important at the next age level. (Butler et al., 1978, p. 29)

Game with rules: This period is from 7 to 11. Dramatic and socio-dramatic play continues to be one of the most important play types at this stage. The symbolic play still has its irreplaceable role in children development. A recent study found the average age for ceasing to engage in child-like pretend play was 11 years old (Lillard, 2015). Game with rules emerges from symbols in the context of social contracts. It's characterized by competition and established regulations. Making and accepting rules are reoccurring themes in child's play. The emphasis on accommodating to rules represents an advance in comprehension over the last stage, when social reality was understood in terms of overt actions and simple, observable roles only.

The existence of this kind of play has some positive consequences for education. First, children were forced to cope with their own desire because of the emphasis on rules. Second, focusing on rules can also lead children to reflect on rules. They may find that they are able to create rules by themselves, but once the rules are created everyone needs to obey them. This can teach children about how social agreements are formed and the importance of following them (Butler et al., 1978).

2.2.1.2 Parten's Theory of Stages of (Social) Play

The Stages of Play is a theory of children's play developed by Mildred Parten Newhall from the social aspect. Parten recognized six stages of play in her theory which is unoccupied play, solitary play, onlooker behavior, parallel play, associative play and cooperative play (Parten, 1932; Johnson et al., 1987).

Unoccupied play: It's the stage when the child is not playing but observing. A child may just stand there and make some random movements. This stage happens in the early months of infant, from birth to about three months (Jona, 2010).

Solitary play: It's the stage when child is alone and only focuses on his or her own activities. The child is uninterested in and unaware of what others are doing. The stage's period differs in various studies, from 3 to 18 months (Jona, 2010) and from 2 to 2½ (Johnson et al., 1987). Jona (2010) indicated that solitary play becomes common in toddlers because of their limitation in social, cognitive and physical aspects. And it's important for all age groups to have time to play by themselves.

Onlooker behavior: It's a transitional behavior where a child watches other playing but does not join in. And child may have a conversation with other children about play, but there is no effort to join the play (Jona, 2010).

Parallel play: It's the stage when children plays separately from others but physically close to each other. During this play, children still play alone but they are interested in what others are doing. They may modify their own play approach by occasionally glimpsing others

play. This type of play is seen as a brief transitional stage from solitary and onlooker play to the socially mature associative and cooperative play (Johnson et al., 1987).

Associative play: It's the stage when the child becomes more interested in other children playing rather than their activities. The child starts to socialize with others. The play may seem to be loosely organized but actually there is no formal organization at all. This play teaches children the spirit of sharing, encourages the development of their language, enhances their problem-solving skills and supports their cooperation thinking (Jona, 2010).

Cooperative play: It's the stage when the child is interested in both other children playing and the activities they are doing. Not like the previous several play stages, the activities in cooperative play are well organized. Rules have been set for all of the participants. This play rarely happens in preschool and kindergarten years because the children at that age still lack social maturity and organizing skills. This play also corresponds to the games with rules which was talked about previously. Jona (2010) claimed that when children move from a self-centered world to an understanding of the importance of social contracts and rules, they begin to play games with rules.

2.2.1.3 Howes's Theory of Social Play Levels

Johnson, Christie and Yawkey (1987) proposed that Parten's theory do provide many supportive opinions of the development of the social play, but some limitations also need to be argued. Some evidence shows that older children alternate between solitary play and interactive play as they develop a tendency to engage parallel play. An article from British Toy and Hobby

Association also states that the solitary play does not disappear even though the following stage of play, social play, becomes common. Even the children in preschool and nursery school tend to alternate between solitary and social play (Goldstein, 2012)

The social play level theory developed by Carollee Howes (1980) has been appreciated because of its valuable statements from observing and coding. It's necessary to research his theory and compare to Parten's theory for a more accurate theory of social play development.

Level 1 is parallel play. Two children engage in the similar play scheme side by side without social contact. The level 1 is exactly the same as the parallel play described in Parten's theory.

Level 2 is parallel play with mutual regard. Two children engage in the same or similar play scheme side by side with little social contact such as eye contact. And they are aware of each other.

Level 3 is simple social play. Two children engage in the same or similar play scheme and each child directs a "social bid" to the others. According to Howes's (1980) explanation, the "social bid" could be smiling, vocalizing, touching, offering or receiving an object, helping with a task, moving a toy, and etc. For example, two children are playing blocks, one child offering another child a cube piece and the other child receiving it.

Level 4 is complementary and reciprocal play with mutual awareness. Two children engage in complementary and reciprocal activities and show single or simple mutual awareness and regard. The complementary and reciprocal activities are each child's action reversing the

other child's in order to demonstrate the awareness of the other. For example, two children push a toy car back and forth; one child chases another and is chased later.

Level 5 is complementary and reciprocal social play. Two children engage in complementary and reciprocal activities and each child directs a social bid. For example, two children are building a bridge with toy blocks together. One child says, "Use this long piece for the bridge deck," and the other child takes the long piece and says, "OK."

Howes's theory detailed the play stages theory from Parten, especially in parallel play. The concepts of the social bid and the complementary and reciprocal activities make the social play evolution procedure much clearer and more understandable. Level 2 explains how the initial social contact started from parallel play. Level 3 and level 4 make the transition between associate and cooperative play much smoother. From my point of view, Howes's theory is an indispensable supplement for Parten's theory.

2.2.1.4 Erikson's Theory of Stages of Psychosocial Development

Erikson's theory of stages of psychosocial development was developed by Erik Erikson in collaboration with Joan Erikson. It's a comprehensive psychoanalytic theory that identifies a series of eight stages that a healthy developing individual should go through for the whole life (William, 2011).

2.2.1.4.1 Rule of stages

In each stage, people face and hopefully master new challenges. Each stage builds upon the successful completion of earlier stages. The failure of completing the challenges of stages may turn into problems in the future.

However, mastery of a stage is not required to advance to the next stage. The outcome of one stage is not permanent and may be affected by later experiences. Each stage has a psychosocial crisis of two conflicting forces. If an individual can successfully reconcile the forces, he or she can develop the virtue corresponding to the stage.

Approximate Age	Virtues	Psychosocial crisis[3]	Significant relationship	Existential question[4]	Examples[4] [hide]
Infancy Under 2 years	Hope	Trust vs. Mistrust	Mother	Can I trust the world?	Feeding, abandonment
Toddlerhood 2–4 years	Will	Autonomy vs. Shame/Doubt	Parents	Is it okay to be me?	Toilet training, clothing themselves
Early childhood 4-5 years	Purpose	Initiative vs. Guilt	Family	Is it okay for me to do, move, and act?	Exploring, using tools or making art
Middle Childhood 5-12 years	Competence	Industry vs. Inferiority	Neighbors, School	Can I make it in the world of people and things?	School, sports
Adolescence 12–19 years	Fidelity	Identity vs. Role Confusion	Peers, Role Model	Who am I? Who can I be?	Social relationships
Early adulthood 19–35 years	Love	Intimacy vs. Isolation	Friends, Partners	Can I love?	Romantic relationships
Adulthood 35–65 years	Care	Generativity vs. Stagnation	Household, Workmates	Can I make my life count?	Work, parenthood
Maturity 65–death	Wisdom	Ego Integrity vs. Despair	Mankind, My kind	Is it okay to have been me?	Reflection on life

Table 2. 2 Erikson's Stages of Psychosocial Development

2.2.1.4.2 Stages

As Table 2.2 shows, from the sixth stage, the age groups go into adulthood, which is beyond the age group of this research. So, only first five stages (from birth to 19 years old) will be explained and studied.

Hope: Trust vs. Mistrust (0 to 2 years old age). The first stage of Erikson's theory centers around the infant's basic needs and how the interaction between the infant and parents lead to trust and mistrust outcome. Erikson (1968) defined trust as "an essential trustfulness of others as well as a fundamental sense of one's own trustworthiness" (p. 96). The primary people to provide the trust or mistrust are parents and secondary are other caregivers.

If the basic needs such as food, comfort and affection are met, the child will learn trust, which also means others are dependable and reliable. If the caregiver or parents failed to provide a secure environment, the child will learn mistrust, which also means others are undependable and unpredictable and even dangerous (Bee & Boyd, 2009).

For sure, child's priority is the need of safe and comfort. While the negative feelings are not necessarily desired, the experience of mistrust allows infant to gain an understanding of the constitution of danger in the later life.

Will: Autonomy vs. Shame/Doubt (2 to 4 years old age). During this stage, parents still play an important role as a security base. Because of the motor development, the child always likes to explore the world around them by using his or her own abilities. Indeed, keeping the child safe is vital; parents still need to make sure they are not being too restrictive to their child.

If caregivers demand too much or enact over-protective behaviors, children may develop a sense of shame and doubt about their abilities. If caregivers encourage self-sufficient behaviors, children will develop a sense of autonomy, which means the sense of solving problem on their own (William, 2011).

Purpose: Initiative vs. Guilt (4 to 5 years old age). Compared to autonomy, initiative entails advanced qualities such as planning before undertaking the actual action for accomplishing a task. Instead of having some simple exploration for the surrounding world, children are learning to master the world around him or her, learning basic skills and principles of physics. Examples can be things fall down but not up, round things roll and cubic things stay. Children also starts to make moves with a purpose. The development of courage and independence inspires children to take initiative and prepare for leadership and goal achievement roles. The project that they take may be readily accomplished, but the project beyond their capabilities will lead to failure. And this may lead to some negative behaviors such as aggression, ruthlessness and overly assertiveness.

If parents and preschool teachers encourage and support children's efforts and, at the same time, help them to make appropriate choices based on their abilities, children develop initiative, which means independence in planning and undertaking activities. Instead, if adults discourage or dismiss the pursuit of independent activities, children develop guilt about their needs and desires (Helen & Denise, 2009).

Competence: Industry vs. Inferiority (5 to 12 years old age). During this stage, children are becoming more aware of themselves as different individuals. They have a great improvement in cognitive development. (Allen & Marotz, 2003) They are able to know the concept of space and time in a more logical way. They develop a better understanding of cause and effect as well. Much more complex learning skills can be found in this stage, such as reading

and writing. Children also start to recognize their special talents during this stage. It's really important for teachers and parents to allow them to pursue their interests. If they are not allowed to do that, they will develop a sense of lack of motivation, low self-esteem and lethargy.

If children are encouraged to pursue a positive task and then get praised for their accomplishments, they begin to demonstrate industry by being diligent, persevering at a task until finished. Instead, if children are punished for their efforts or if they find they are incapable of meeting teacher or parent's expectations, they develop the feeling of inferiority about their capabilities (Crain, 2011).

Fidelity: Identity vs. Role Confusion (12 to 19 years old age). During this stage, adolescents start to be concerned how they appear to others. They also want to know the roles that they will play in the adult world. Erikson proposed that most adolescents are able to have the sense of identity regarding who they are (Gross, 1987). The scope of the identities includes occupation, gender roles, politics, cultures and religion.

But one of the difficulties in establishing the sense of identity is to figure out a way to deal with 'the person one has come to be' and 'the person society expects one to become.' No matter how an adolescent was raised, the personal ideologies are chosen by him or herself, which may lead to conflict with adults over religious and political orientations. According to Erikson, when an adolescent has balanced both perspectives of 'what have I got' and 'what am I going to do with it', he or she has established the identity (Gross, 1987).

2.2.1.5 Gallahue's Theory of Motor Development

Gallahue's theory of motor development divided the concept of motor development into two terms, namely movement abilities and physical abilities (Gallahue, 1976; Gallahue & Ozmun, 2002).

2.2.1.5.1 Movement Abilities

"'Movement abilities' refers to the development and refinement of a wide variety of fundamental movements" (Gallahue, 1976, p. 3). Movement abilities consist of three categories: stability, locomotor, and manipulative.

Stability abilities are the developing patterns of movement that permit children to gain and maintain a point of origin for the explorations that they make through space. This type of abilities is always seen as non-locomotor movements, such as bending, stretching, twisting and turning.

Locomotor abilities involve "projection of the body into external space by altering its location in either a vertical or horizontal plane" (Gallahue, 1976, p. 4). The activities can be running (horizontal) or jumping (vertical).

Manipulation abilities involve imparting force to objects such as throwing a ball, pushing or pulling a toy vehicle, and stacking toy blocks.

2.2.1.5.2 Physical Abilities

The physical development aspects of the motor domain can be classified as either physical fitness or motor fitness.

Physical fitness is generally considered to be "the ability to perform one's daily tasks without undue fatigue" (Gallahue, 1976, p. 8). It also is a state in which ample reserves of energy should be available for recreational pursuits and to meet energy needs. Physical fitness includes muscular strength (the ability of the body to exert a maximum force against an external object on the body), muscular endurance (the ability to exert force against an external object on the body for several repetitions), circulatory-respiratory endurance (an aspect of muscular endurance specific to the heart, lungs, and vascular system), and flexibility (the ability of the various joints of the body to move through their full range of motion). (Gallahue, 1976)

Motor fitness is generally thought of as one's performance abilities as influenced by the factors of speed, agility, balance, coordination, and power. According to Gallahue (1976), speed is the ability to move from one point to another in the shortest time possible; agility is the ability to change the direction of the body rapidly and accurately while it is moving from one point to another as fast as possible; balance is a complex quality which is influenced by vision, the inner ear, cerebellum, proprioceptors, and the skeletal muscles; coordination is the ability to integrate separate motor systems with varying sensory modalities into efficient movement.

2.2.1.5.3 Phases of Motor Development

> Locomotor, manipulative and stability movement activities are experienced at all levels in the total life experience which may be classified motorically into developmental stages. These developmental stages correspond roughly with the phases of development outlined in the following paragraphs. (Gallahue, 1976, p. 4)

By compiling the previous researches, Gallahue and Ozmun (2002) proposed a two-dimensional model for classifying movement development (see Table 2.3). This two-dimensional model of motor development emphasizes: (1) the intended function of the movement task as expressed in the three movement categories of stability, locomotion, and manipulation; (2) the phases of motor development as expressed by their complexity through the terms reflexive, rudimentary, fundamental, and specialized movement phase.

Phases of Motor Development	Intended Function of the Movement Task		
	Stability (Emphasis is on body balance in static and dynamic movement situations)	**Locomotion (Emphasis is on body transportation from point to point)**	**Manipulation (Emphasis is on imparting force to or receiving force from an object)**
Reflexive Movement Phase: Involuntary subcortically controlled movements in utero and early infancy	• Labyrinthine righting reflex • Neck righting reflex • Body righting reflex	• Crawling reflex • Primary stepping reflex • Swimming reflex	• Palmer grasp reflex • Plantar grasp reflex • Pull-up reflex
Rudimentary Movement Phase: The maturationally influenced movements of infancy	• Control of head and neck • Control of trunk • Unsupported sitting • Standing	• Crawling • Creeping • Upright gait	• Reaching • Grasping • Releasing
Rudimentary Movement Phase: The basic movement skills of childhood	• Balancing on one foot • Walking on a low beam • Axial movements	• Walking • Running • Jumping • Hopping	• Throwing • Catching • Kicking • Striking
Specialized Movement Phase: The complex skills of later childhood and beyond	• Performing a balance beam routine in gymnastics • Defending a goal kick in soccer football	• Running the 100-meter dash or hurdles event in track • Walking on a crowded street	• Performing a goal kick in soccer or football • Striking a pitched ball

Table 2. 3 Gallahue’s Two-dimensional Model for Classifying Movement

Reflexive movement phase: The reflexive movement of fetus and newborn are considered to be the first phase of motor development. Reflexive behaviors are involuntary and subcortically controlled (Gallahue, 1976; Gallahue & Ozmun, 2002).

Rudimentary movement phase: Rudimentary movements begin developing in the infant from shortly after birth to approximately 2 years of age. They are "maturationally determined and are characterized by a highly predictable sequence of appearance" (Gallahue & Ozmun, 2002, p. 47). The movements involve the stability movements such as gaining control of the head, neck, and trunk along with learning how to sit and stand unaided. They involve the locomotor activities such as creeping, crawling, and walking. They also involve the manipulation experiences such as reaching, grasping and releasing objects.

Fundamental movement phase: This phase of motor development represents a time in which young children are actively involved in exploring and experimenting with the movement capabilities of their bodies. The involved stability activities can be beam walk and one-foot balance; the involved locomotor activities can be running and jumping; the manipulative activities can be throwing and catching.

This phase is divided into three stages: initial stage, elementary stage, and mature stage. The initial stage is at the age between 2 to 3 years old. It represents the child's first goal-oriented attempts at performing a fundamental skill.

The elementary stage involves greater control and better rhythmical coordination of fundamental movements. The synchronization of the temporal and spatial elements of

movement are improved, but patterns of movement at this stage are still generally restricted or exaggerated, although better coordinated. (Gallahue & Ozmun, 2002, p. 49)

The mature stage within the fundamental movement phase is characterized by mechanically efficient, coordinated, and controlled performances. Children at this stage should be at 5 or 6 years of age. The manipulative skills that require visually tracking and intercepting moving objects include catching, striking, and volleying.

Specialized movement phase: The specialized movement abilities are an outgrowth of the fundamental movement phase. In this phase, movement abilities are becoming tools which can be applied for the use of daily life, recreation and sports (Gallahue, 1976; Gallahue & Ozmun, 2002). The fundamental movements of hopping and jumping may transform to activities like rope jumping or dancing in the phase of specialized movement.

This phase can be divided into three sub-phases. The first stage is called transitional stage. It's the period when children firstly apply the skills they learned in the fundamental movement phase to the performance of specialized movement in sport and recreational settings. Walking on a rope bridge, jumping rope, and playing soccer are all examples of common transitional skills. The second stage is called application stage. During this stage, instead of doing all activities as "trials" in transitional stage, children start to choose their favorite activity based on their increased cognitive sophistication and the broadened experience base as well as the environmental factors. The last stage is lifelong utilization stage. It's the stage that individual makes further refinement of the inherited interests from the previous stage and applied to a lifetime of daily living, recreational, and sports-related activities (Gallahue & Ozmun, 2002).

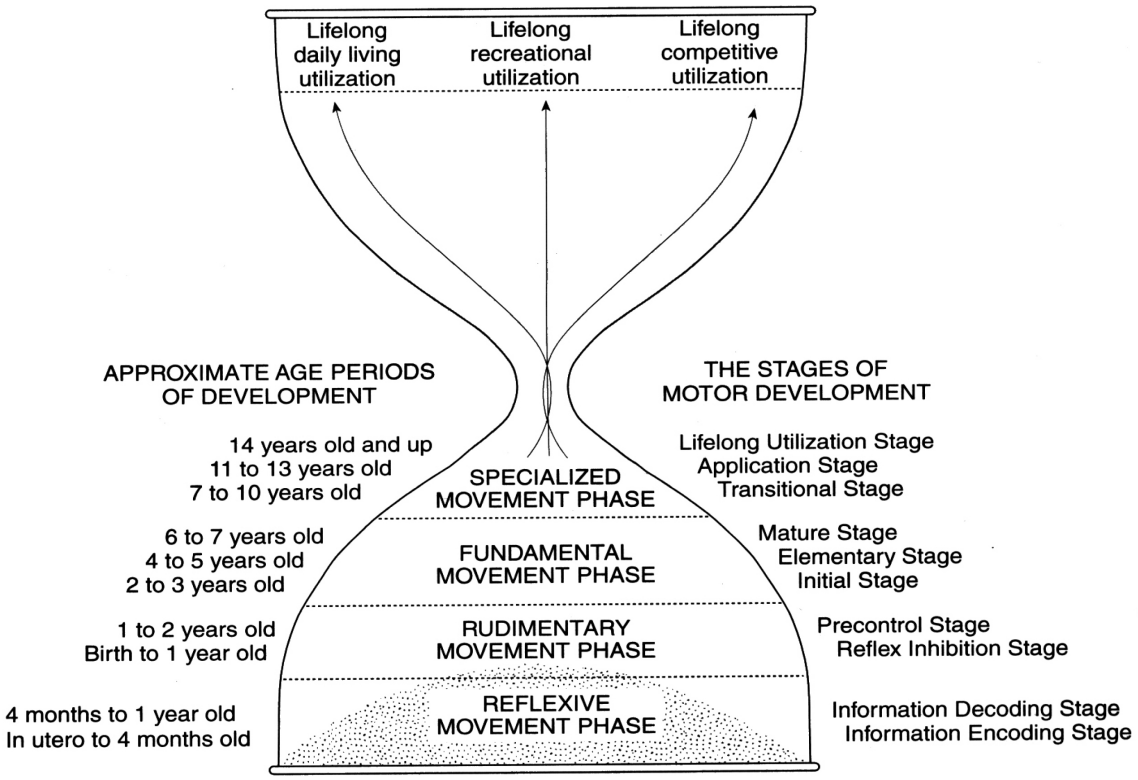

Figure 2. 2 Phase of Motor Development

Gallahue & Ozmun (2002) proposed the motor development phases model by using an hourglass figure (See Figure 2.2). This can represent how the specialized movements are developed and concentrated initially from the reflexive movements as well as the how the movements move into the lifelong utilization for daily living, recreational and competitive use.

2.2.2 Aspects of Children Development

This section will focus on summarizing how play helps children to develop their abilities in different aspects. Butler, Gotts and Quisenberry (1978) stated that play development parallels all other early development in a general order. Among all the paralleled development aspects, three major areas need to be paid attention to.

> 1st, play feeds on and into children's physical or motor development. 2ndly play development also parallels social development. Finally, play feeds on and into the child's overall ability to deal with physical reality. We will refer, in this text, to changes in this overall ability as cognitive development. (Butler, Gotts and Quisenberry, 1978, p. 26)

So in this part, play theories and thinking as well as child development research will be categorized according to four child development aspects: cognitive development, social development, motor development and other developments. The involved theories not only contain the systematic modern play theories reference earlier, but also include some related theories, opinions and discussions.

2.2.2.1 Cognitive Development

The theory of play and cognitive development from Piaget which was presented earlier provides a well-developed structure about the cognitive stages corresponding to the dominant type of play for children in different age groups. From birth to 2 years old, children are situated at the sensorimotor stage and the dominant type of play is sensorimotor/practice play. From 2 to 7 years old, children are situated at the pre-operational stage and the dominant type of play is symbolic play. From 7 to 11 years old, children are situated at the concrete operational stage and the dominant type of play is games with rules.

There are four significant cognitive variables that play contributes to, which is IQ, conservation ability, problem solving skills and creativity (Johnson et al., 1987).

IQ. Play, especially make-believe play, contributes greatly to IQ development. Vygotsky (1976) believed that play serves a direct role in cognitive development. He found that children in

the early ages do not have the ability of abstract thinking, which means they are not able to think about a pen without seeing one. With the engaging of make-believe play, they try to use some objects to stand for other things, such as using a stick to stand for a pen. Then, for children, the meaning starts to separate from the actual object. As a result, children develop the ability to think about the meaning and the object independently. This statement is also similar as the statement of the symbolic function sub-stage that presented earlier. Symbolic function sub-stage is when children are able to perceive the objects without seeing them. Some research even indicated that there is a promising potential that play can increase IQ. Johnson, Ershler and Lawton (1982) proposed that two types of play have shown a positive influence on IQ, which is socio-dramatic play and constructive play.

Conservation. Conservation shows the ability to understand certain properties of objects. Rubin, Fein and Vandenberg (1983) argued that when children are able to engage in make-believe play, they have already mastered two cognitive conservations which is decentration and reversibility. Decentration is the realization that they can be themselves and the imagined role at the same time. Reversibility is the ability to switch the roles back to themselves from the make-believe play at any time.

Problem Solving. Bruner (1972) contended that play contributes to children's problem-solving ability through increasing their behavioral options. He stated that the meaning of play is more important than the end of play. Because children do not require accomplishing some exact goals when playing, they will make experiments about new or even unusual ways of play. And

when they come across some real-life problems, they may use the same approach. So play can promote the problem solving ability by increasing children's behavioral options.

Creativity. Creativity is treated as the strongest link between play and cognition (Johnson et al., 1987). Sutton-Smith (1967) pointed out that during make-believe play, the symbolic transformations occur and reflect a similar effect on children's mental flexibility and creativity. Butler, Gotts & Quisenberry (1978) also proposed that children use play to express their creativity. Role-playing allows them not only to show their creativity but also display the internal feelings. Building structures and art toys provide children with creative, expressive outlets.

2.2.2.2 Social Development

Play has a key role in social development by providing a context in which children can acquire important social skills as well as the ability to understand other people's thoughts. Thus, when social environment influences the play, play also affects children's ability in the social environment. Social skills and perspective taking will be reviewed.

Social Skills. "All social play is rule governed" (Johnson et al.,1987, p. 99); even the simple infant game like peek-a-boo requires the right sequences. Also, the rules for play have a great difference from the games with rules which Piaget suggested in the cognitive development theory. Instead of defining the rules before game, rules for play are set by players during the course of the play. Therefore, children are not only learning and following the rules but also thinking about the nature and meaning of rules.

Garvey (1974) indicated that group play such as socio-dramatic play requires children to be able to construct and vary the theme of play together. In order to accomplish a successful socio-dramatic play together, children need to agree to adopt each one's role and to choose the most appropriate object for identity substitution. The story sequences also need to be decided cooperatively. All of these actions require children to develop and master the communicating and perspective taking skills (which will be discussed below). Social-dramatic play ability correlates with social skill (Butler et al., 1978).

Perspective Taking. According to the definition from Johnson, Christie and Yawkey (1987), perspective taking is "the ability to see things from other people's point of view" (p. 101). It involves what other people see, think and feel, which can also be said as visual perspective taking, cognitive perspective taking and affective perspective taking.

The reason why perspective taking is hard to develop is because its role is deeply opposed to the egocentric human nature. Humans are born to be egocentric. With the development of the mind and the cultivation of the external environment, step by step, the child will realize the world is not his. He starts to realize his mother is separated from him; he starts to realize the objects exist even though he doesn't see them. And during socio-dramatic play, he has to fit himself into the role with the role's personality, which promotes the ability to think from another person's perspective.

2.2.2.3 Motor Development

Gallahue's phases of motor development established a well-organized motor development theory. The reflexive movement phase is the initial involuntary, subcortically controlled movements; the rudimentary movement phase stands for the time that child step by step starts to gain the basic voluntary movements which have a great meaning from the aspect of survival; the fundamental movement phase is the period in which children are making explorations and experiments of their body capabilities; and the specialized movement phase can represent how children transform from "what I can do" to "what I want to do" from the perspective of motor activity.

2.2.3 Aspects of Play Development

This section will focus on how play develops with children's development in different aspects. The aspects all correspond to the aspects of children development in the previous section.

2.2.3.1 Development of Symbolic Play

Symbolic play is the dominant play type during the second stage, pre-operational stage in Piaget's cognitive development. As mentioned earlier, Piaget (1962) defined three types of symbolic play: the application of one symbolic scheme to new objects; the application for the substitution of another object or another person's role in one symbolic scheme; planned combinations of symbolic schemes and a sequence or pattern of behavior. These three types of

play are listed with a timeline sequence. More development details will be discussed in the following paragraph.

Many researchers traced the origin of symbolic play back to the development of pre-symbolic play which occurs before 2 years old (Watson & Jackowitz, 1984). Some simple pre-symbolic plays are observed such as self-as-agent when the infant is 12 months. Examples can be pretending to be sleeping, eating, drinking, and etc. These behaviors do not meet any real needs or purposes.

During the second year of life, the infants become able to pretend and use objects substituted for other things. Although these pretend activities are still purposeless and unrelated to real needs, they are self-directed. At around 18 months of age, the child starts to be capable of outer-directed symbolic play. And this is the period when what Piaget (1962) called genuine symbolic play starts to unfold. Pretend transformation contains two sides: one is object substitution (so-called recipient objects), and the other is agent substitution (self-as-agent, mother-as-agent, etc.). Watson and Jackowitz (1984) stated that each type of transformation has its own complexity level. Self-as-agent and a realistic toy as the recipient objects are the simplest symbolic play, which occurs more often at a relatively young age. The more differences that the substituting object is versus to the real object, the more complex that the symbolic play becomes. Using a toy banana to substitute a phone is much simpler than to substitute a plane or a car because the shape of a banana is much more similar to a phone versus a plane or a car. And self-directed or self-as-agent behaviors are treated as the first signs of symbolic play in infancy.

During the second and third years of life, the child is able to perform complex play such as using two or more consecutive acts to reflect one similar topic. The content of such play is always familiar and comfortable for child, and the child will probably not interact with a real playmate. However, the play often involves another imagined person such as a teacher, a nurse, or a worker who can always be there to meet children's need and enhance the enjoyment in the play. Such involvement can be viewed as a significant foundation for children's future social development (Johnson et al., 1987).

During the third year, most children's play starts to involve a role for another person which normally would be mother or other intimately familiar family member. This newly adopted role is very difference from the earlier purely pretend play with objects, which suggests the child is able to realize the role identity behind the pretend actions. The characteristic of the role controls the play actions and the role enactment or role-play dominates how pretend play will be. Garvey (1979) states that the significance of role enactment is not only in the awareness of other people, but also in the understanding of role attributes, relationships and role-appropriate actions. Garvey and Berndt (1977) also proposed four types of roles: The first one is called functional roles, which is triggered by the objects or activities, such as a toy bowl triggering a role-play activity like cooking. The second is called relational roles, which suggests the family roles such as child-mother or wife-husband. The third is called character roles, which is stereotypical (fireman, witch) or fictional (characters with proper names such as Master Yoda, Pinocchio, or Batman). The last is called peripheral role, which means real and imagined friends.

During the preschool years, symbolic role-play starts to move away from the daily familiar themes, such as pretending to be a teacher or a doctor, towards to an out-of-ordinary theme with the expression of personal interests, which shows a tendency to move from the first and second type of role-play to the third type.

The ultimate version of symbolic play is the ability to imagine with no objects at all. According to Johnson, Christie and Yawkey (1987), the child at this stage is "versatile in improvising with props and substitute objects of all types" (p. 57).

> High levels of symbolic development are seen in the child's being able to take on a variety of diverse roles in collaboration with peers, engaging innovatively and with great enjoyment in sociodramatic and fantasy themes ranging from the most commonplace to the most extraordinary. Concentration, persistence, attention to detail, and seeing the play episode as a whole are other manifestations of symbolic development. (p. 57)

2.2.3.2 Development of Social Play

In the earlier section, two social play theories have been presented. Parten's theory of social play stages provides a general sequence of social play development, from the "un-play stage"—unoccupied play and "play alone stage"—solitary play to "the sprouting of the interactive play"—onlooker play and parallel play, then to the "well-developed social play"—associative play and cooperative play. Howes's theory of social play levels serves as a indispensable supplement for Parten's theory.

Butler, Gotts and Quisenberry (1978) also introduced four stages of social aspects when talking about productive play, the sub-stage in symbolic play.

> 1st children can and may carefully observe someone else constructing, work at constructing alone, 2nd play at constructing next to another child without interacting, 3rd play next to another child while observing him from time to time, and 4th (some children) play interactively at constructing things with one or two other children. (p. 28)

These four stages are similar to Parten and Howes's theory. This first stage is really similar to the onlooker play; the second stage is pretty much the parallel play; the third stage is described as parallel play with mutual regard; the last stage is like the simple social play. Because Butler, Gotts and Quisenberry (1978) defined the stage of productive play as occurring between two and four years of age, it's easy to draw a conclusion that the transition periods from onlooker play to parallel play then to simple social play is between two to four years old.

During the stage of reproductive play, Butler, Gotts and Quisenberry (1978) proposed, "increased productive skills and increased social contact lead to an increase in the child's potential for reproducing the social realities experienced. This happens especially when children use their imaginations to play different social roles" (p. 29). This is the time that dramatic play and socio-dramatic play start to emerge, from four to seven. From the perspective of social play, it's about the time that complementary and reciprocal play or cooperative play starts to dominate. From the perspective of symbolic play, it's about the time that socio-dramatic role enactment play starts to dominate.

2.2.3.3 Development of Motor Play

In the section of Gallahue's theory of motor development, it is presented that individual in each phase shows different motor capabilities, which can deeply affect the motor activities that children would participate in. These motor activities, if said in another way, are motor play.

Johnson, Christie and Yawkey (1987) also proposed some milestones for the development of motor play from birth to six years of age. Newborns only do rudimentary movements such as blinking and throwing their arms. Motor abilities that newborns perform have two aspects, the general ability to move body parts in an uncoordinated and random way and the automatic, "involuntary swift and finely coordinated reflexes" (p. 58). From the perspective of hand skill manipulation ability, an infant does not have small-muscle control at birth. During the first month of life, the limbs act in unison like a fin; during the second month, infants might hold an object briefly; at four through six months, infant are able to trap an object with two hands; by the seventh month, objects can be held between the thumb and several fingers; in the eighth month, babies can transfer objects from hand to hand. During two to three years of age, the gross-motor activity (large muscles for mobility) as well as the fine-motor activity (hand muscles, hand-eye coordination) is continually developing. Children during this period can walk easily, can run, and can go up or down stairs. Preschoolers from three to four years of age demonstrate further developmental progression in motor skills and motor play. They can run easily with good balance, can tiptoe and stand on one foot, and can climb stairs with one foot each step. Children from four to five years old achieve further motor mastery. They can

skip, climb, and hop easily. They enjoy chasing each other and simple athletic activities. From five to six years of age, the development of gross-muscle control makes it possible for children to engage in motor play as acrobatics and trapeze tricks. Well-developed fine-muscle control makes it possible for children to cut, trace, draw, and paste successfully.

2.3 Role of Toy

As proposed in the earlier section, toys are seen as the material artifacts of play (Mergen, 1982). Newson & Newson (1979) also discussed the relationship between toys and play as well as the essential role of play during the play.

> We do not play as a result of having toys; toys are no more than pegs on which to hang our play. In theory, toys are not needed; the child could happily wander through her fantasy world, her imagination supplying all that was wanted. (p. 12)

Because of the wild extendibility and unpredictable complexity of human imagination, children always need to have a solid and tangible reference point to start at. So a toy is not only the "peg" that relies on play for survival, but also a foundation for play to build on. With this foundation, children are able to express their imaginations with a certain direction in order to extend their maximum potential, just like how language makes complicated thought easier to understand.

2.3.1 Toy and Plaything

Newson and Newson (1979) described toys as anything doing with play. This is correct from the generalized standpoint but incorrect from the narrow standpoint. Mergen (1982) suggested the term of plaything in his book *Play and Playthings*.

> A 'plaything'—a stick, for example—was not a stick but a horse to ride, a thermometer for playing doctor, a writing or drawing tool for making on the ground, … A 'plaything' could be and was anything the mind willed—for a moment, an hour, for months or years. Play was metaphoric action. (p. 103 - 104)

A plaything is every object associated with play, including toys and other "toyish" objects. As proposed in the section "Development of Symbolic Play", the non-toy plaything is widely used in pretend play, like using a banana to substitute for a phone. But a toy is not like the other playthings, it's designed to be used only for play. When commenting about toys, Remise and Fondin (1967) said, manufactured toys are made by adults to appeal and sell to other adults. This is because most of the time, the parents are the final decision makers for any toy purchasing. Although some toy design strategies showed that children could get involved in the toy design process, such as asking children to test and judge the prototype product like the American TV show "The Toy Box", adults are still the final decider. Sutton-Smith (1979) proposed the study of toys' history shows that toys appeared both in adult ritual and in children's play at the same time. Meeting the needs that satisfy both children and adult aspects are equally important.

2.3.2 The Idea of Open-ended

Merriam-Webster defined open-ended as “not rigorously fixed: such as permitting or designed to permit spontaneous and unguided responses” (“open-ended”, n. d.). However, the definition of open-ended play is far more complex. One important thing when discussing about the open-ended play that people always talk about is the idea of free play. So first of all, we need to research free play and the relationship between free play and open-ended play.

2.3.2.1 The idea of Free Play

Free play is described as the play started by children playing, which provides them unlimited freedom to choose how, what and when to play (Santer, Griffiths & Goodall, 2007). Games with rules stand on the opposite side. According to French Sociologist Roger Caillois (1961), two terms have been used with exactly contrary meanings, which is Ludus (Games) and Paidia (Free play). Ludus means the game that is for solving a particular problem or concern, which includes chess, hide-and-seek and all kinds of sports games. In Ludus play, rules to obey are significant, while Paidia, on the other side, is rule-less and unrestricted. Morrison, Viller and Mitchell (2011) also defined free play as a play activity with features like non-narrative, non-competitive, and without a logical ending point. They also pointed out that there are two different aspects in free play. The first one is that the play is able to constantly rejuvenate with its participants who serves as co-constructors. They can discover the new offers of play from the product over time. Secondly, the play is free from any predetermined meanings which means participants can build their own meaning and invent their own way to interact with the product.

Games (ludus)	Free play (paidia)
Structure	Chaotic
Finite, with (end) goals	Infinite, no logical ending point
Fixed (game) rules	Improvisation, spontaneity
Predefined	Own construction of meaning
Challenge, competition	Sensation of play, Expression

Table 2. 4 The Property Differences between Games and Free Play

Bekker, Eggen and Valk (2013) concluded the differences of properties between games and free play, illustrated in Table 2.4. They also proposed that although the games and free play have a dramatic distinction, there is a large grey area in between. And open-ended play as they stated is positioned in this grey area.

2.3.2.2 Definition of Open-ended Play

It's not easy to assume that open-ended play, situated in the grey area between games with rules and free play, may have some rules for play but will not totally predefine the play. Bekker, Eggen and Valk (2013) described that open-ended play can slide either way, depending on how it grows. When players are concerned more about rules and goals, the play will slide towards to a game; when players play only for sensation, the play will slide towards free play. "Free play differs from open-ended play, as it stresses the freedom children have to play with whatever whenever they want; Open-ended play somewhat restricts children in their free play as it offers objects with design intentions" (Bekker, Eggen & Valk, 2013, p. 2).

So open-ended play can be defined as play without predefined rules in which players can attach the meanings that they design to the play properties when they are playing. On one hand, the open-ended play cannot be too open, or there will be no design properties, just like free play. On the other hand, open-ended play cannot be too restricting. Too many rules will set up a limit for achieving more potential outcomes. Open-ended play is focused on searching for the balance point between spontaneity and structure.

2.3.2.3 Role of Open-ended Toys

Open-ended toys are the toys that are able to provide open-ended play. As discussed earlier, the open-ended play is situated at the grey area between games and free play. It is reasonable to assume that the open-ended toy is also situated in the grey area between un-designed playthings (wood stick, blanket, box) and defined toys (chess, puzzle, display model). Frost, Pei-San, John and Candra (2004) described the defined toy as closed-ended toy, which provides the play with a determined outcome, a right answer and a restriction on individual differences. *Creative Playthings*, an American trade magazine for toy and game industry, believed that "the typical American child has far too many toys and that most of these toys are at once too literal in design and capable of doing too many literal things" (Mergen, 1982, p. 116). This comment reveals the urgency for children to own more open-ended toys.

Newson and Newson (1979) mentioned a vital quality that toys have, called functional versatility. "In general, toys which have a high degree of functional versatility also have a quality of being non-descript, and it is precisely because of this that they stand-in so successfully for

whatever specific object the child has in mind. … A toy is ambiguous allows a child to use her imagination in filling out the details" (p. 14). A toy with low functional versatility will only be used in rigidly defined ways, which demonstrates the use of a closed-ended toy. The toy with high functional versatility will be exploited by the child in all kinds of different roles to suit her moods, personality and ability, which demonstrates open-ended play.

Newson and Newson (1979) emphasized that higher functional versatility of the two is correlated with the lower complexity of the structure of the toy, such as an infinite-function wooden box versus a single-function jack-in-the-box, but a toy with realistic details does not mean it's an unnecessary toy. "Children get a great amount of pleasure and satisfaction from realistic detail that mirrors the world they live in" (p. 14). It is also doubtful that realistic toys have less functional versatility. During dramatic play, children can use different realistic toy combinations to create different themes. They can use a toy phone and toy cookware to develop a take-out pizza restaurant theme; they can use toy cookware and baby doll to make a mother-daughter busy morning theme. So, the complexity of a toy cannot define the functional versatility that it has. Newson and Newson (1979) pointed out another example: when they were testing newly-designed beautiful basic-shaped wooden animals with children, they found that instead of playing with these abstract wooden toys, children would love to spend more time playing with the mass-produced polythene animals imaginatively and creatively. In the research of development of symbolic play, realistic toy and abstract toy are preferred in different age groups due to the different imaginative ability and cognitive development. Goldstein (1994) proposed a

similar idea that “as children’s representational skills become more developed, they are able to use less realistic objects in their play and, consequently, can make more transformations” (p. 20).

In this research, only the open-ended toys will be applied to the final solution. It’s not because closed-ended toys are less important than open-ended toys. Indeed, open-ended toys provide children the chance to explore the toy by themselves and define the play approaches according to the development of their abilities. Closed-ended toys do give the same amount of great benefits. Educational toy must be closed-ended because delivering knowledge is a really serious activity. Using an open-ended way to answer the question may lead to the misunderstanding of the knowledge, which is what we definitely would like to prevent. Games with rules as we mentioned earlier, are especially beneficial for elder children in the social aspects. And it’s also the foundation for children to form the concepts of social rules and social virtues.

2.3.3 Toy types

Toy Industry Association (2013) provides a comprehensive toy category with twenty-one major types and more sub-types with explanations. In this section, the toy types will be listed and analyzed. One aspect is to analyze if the toy belongs to the open-ended toy; another aspect is to determine if the toy is suitable to be applied into the future methodology and why or why not.

2.3.3.1 Action Figures

> **Action Figures, Playsets and Accessories:** Includes licensed and theme figures that have an action-based play pattern. Also includes clothing, vehicles, tools, weapons or play sets to be used with the action figure.

Role Play (non-costume): Includes role-play accessory items that are both action themed and generically themed. This category does not include dress-up or costume items, which have their own category. (Toy Industry Association, 2013, p. 1)

The Action Figures category belongs to open-ended play. Although they also include licensed and themed figures, the playing rules are not defined by designers at all. Children can develop the story lines by using action figures by themselves.

2.3.3.2 Art and Crafts

Chalk, Crayons, Markers Paints and Pencils: Includes singles and sets of these items. (e.g., box of crayons, bucket of chalk).

Reusable Compounds (e.g., Clay, Dough, Sand, etc.) and Kits: Includes any reusable compound, or items that can be manipulated into creating an object. Some examples include dough, sand and clay. Also includes kits that are intended for use with reusable compounds

Design Kits and Supplies—Reusable: Includes toys used for designing that have a reusable feature or extra accessories (e.g., extra paper). Examples include Etch-A-Sketch, Aquadoodle, Lite Brite, magnetic design boards, and electronic or digital design units. Includes items created on the toy themselves or toys that connect to a computer or tablet for designing / viewing.

Design Kits and Supplies—Single Use: Includes items used by a child to create art and sculpture projects. These items are all-inclusive kits and may contain supplies that are needed to create the project (e.g., crayons, paint, yarn). This category includes refills that are sold separately to coincide directly with the kits. Also includes children's easels and paint-by-number sets. (Toy Industry Association, 2013, p. 1)

Most of the sub-categories in Arts and Crafts belong to open-ended toys except the single use design kits and supplies. The toys in this sub-category are designed to use only once. During

the play, the toy can have an open-ended outcome. After that play, the toy is not playable anymore. But this re-playable quality is one of the most significant aspects in open-ended toys.

Other than the single use category, all of them can fit in open-ended play. And the toys in this category towards more to the free play material. Instead of using raw material such as stone or brick to draw on the wall, children can use chalk, crayons and pencils to draw on a paper, which makes it much easier and safer for them to express their imagination.

2.3.3.3 Battling Toys

Battling Toys, Playsets and Accessories: "Includes toys that have an 'action' based play pattern (e.g., battling and combat). This category would also include playsets as well as battling tops. These toys do not have a full body figure" (Toy Industry Association, 2013, p. 1).

The battling toys are designed only for battling. They are designed for children to play and compete with each other. Not like action figures with a theme of army or battle, the only game this type of toy provides is to battle with each other and the only outcome will be to win or lose. The outcome and the play are fully defined by designers. So this type of toy belongs to the closed-ended toy category.

2.3.3.4 Building and Construction

> **Building Sets and Accessories:** Includes items that have interlocking pieces that can be taken apart and allow for building in multiple ways. Also includes any accessories that go along with the building set (wheels, mini figures, etc.). This category includes building toys for all ages but does not include traditional blocks, which would be included in the infant and preschool categories for which they are age-appropriate. (Toy Industry Association, 2013, p. 1)

Building and construction toys are classic open-ended toys. Although some toys can have instructions for “how to make a theme step by step”, it is absolutely children’s choice to follow it or not. From my point of view, the instruction of building and construction toys is more like a recommendation. Children can always build up something from their mind successfully.

2.3.3.5 Collectible Trading Cards and Toys

> **Collectible Trading Cards:** Includes cards that are designed to be collected and traded. There is no game play involved.
> **Collectible Trading Toys and Accessories:** Includes toys that are designed to be collected and traded by children. Can include bracelets, trading cards, stickers, and pencil tops / erasers. Does not include toys that have met the criteria to be placed within another existing category (e.g., Action figures, Dolls, Plush). (Toy Industry Association, 2013, p. 2)

One important modifier when explaining the collectible trading cards and toys is designed to be collected and trade with no game play involved, because the collecting and trading itself is the only meaning of this type of toy. So, it is not hard to draw the conclusion that this type of toy belongs to closed-ended toy.

2.3.3.6 Costume and Dress-Up

Costume and Dress-Up and Accessories: “Includes all dress-up items and Halloween costumes. Also includes nail art, hair chalk and glitter, etc.” (Toy Industry Association, 2013, p. 2).

Costume and dress-up can be seen as an important accessory for open-ended role-play. But the function of these items is unchanging. The costume clothes can only be used to wear; the

nail ink can only be used to decorate nail; the hair chalk can only be used to dye hair. So they belong to the closed-ended toy.

2.3.3.7 Dolls

> **Display Dolls and Accessories:** Includes dolls / figures of any size and their accessories that are meant primarily for display and not generally intended for play. Higher-end fashion themed dolls with a retail price of over $100 are included in this category.
> **Dollhouses and Accessories:** Includes dollhouses with a high degree of detail, as well as furniture or any other accessory designed for use within the dollhouse. These items are miniature versions of real life items. Does not include dollhouse play sets intended for use by fashion dolls and or mini dolls.
> **Fashion and Styling Dolls, Play sets and Accessories:** Includes dolls / figures that are fashion themed (i.e. various outfits and accessories are available for the doll). The primary play is fashion and / or hair play. Clothing and accessories intended for fashion-themed dolls are included in this category. Dollhouses intended for fashion dolls would be categorized here.
> **Mini, Figurines and Playsets and Accessories:** Includes dolls / figurines that are up to including 4.5 inches in height. These dolls can be human or non-human in appearance, such as mermaids, ponies, and turtles.
> **Nurturing Dolls and Accessories:** Includes dolls that have general characteristics of a baby or infant. The play pattern revolves around caretaking similar to how a parent would care for a baby (e.g., feeding, changing, strolling, etc.). This would also include special feature nurturing dolls that talk, wet, feed, etc., as well as nurturing doll clothing and accessories (stroller, car seat) intended for the nurturing doll. (Toy Industry Association, 2013, p. 2)

Dolls are a pretty common toy type in the childhood, especially in make-believe play. When designing dolls, designers will always think about how dolls are used by children to develop their story line. And that's the reason why dollhouses and other accessories are also

important when children are playing with dolls. Except for display dolls, all the sub-types can provide children open-ended play.

2.3.3.8 Educational

> **Electronic Learning Systems** (for 5+): Includes electronic learning toys (including tablets) created for kids ages 5+.
> **Infant- Electronic Learning:** Includes electronic learning toys created for kids up to age 3.
> **Preschool Electronic Learning:** Includes electronic learning toys created for kids ages 3 to 5.
> **Maps, Globes, etc.:** Includes special feature and non-special feature maps, globes, etc.
> **Science:** Includes all toys that teach kids about the sciences (e.g., astronomy, chemistry, earth science, archaeology, etc.). (Toy Industry Association, 2013, p. 2)

Electronic toys can be complicated to analyze. App-based electronic toys, such as iPad, Nintendo Switch, PlayStation Portable, are able to update the play content based on newly developed applications, which is a totally different approach compared to regular physical-based toys and other electronic toys. So, the app-based electronic toys will not be included in my method scope.

Educational toys are all closed-ended, because the knowledge that the toy delivers is unchangeable, and the role for the educational toys is to teach children this knowledge. Maps and globes are designed to provide the geographical knowledge only; science toy does the same thing as well. An astronomy toy only delivers the astronomy knowledge, a chemistry toy only delivers the chemistry knowledge.

2.3.3.9 Games & Puzzles

Brainteasers: Includes games that are characterized by problem solving and are challenging to a players' mind. The games may be two-dimensional or three-dimensional and include shapes, colors, numbers, and letter / word problems.

Cards—Basic: Includes games with cards that can be played in a group or alone. Would not include cards created primarily for trading or collecting.

Cards—Strategic Trading: Includes the collection of strategic trading-type cards that may be licensed and involve a level of strategy, as well as game play between more than one player. Trading cards that are limited to collection and or swapping with no game play would not fall in this category. Those would be found in collectible trading cards and toys.

Electronic Handheld/ Tabletop Games: Includes electronic handheld games that have an LCD screen, and are electronic in nature. All other types of gaming units (Nintendo, PSP, DS, etc.) that do not have product specifics of the TV gaming systems, do not belong within the Toys Hierarchy – they are included in video games.

Game—Adult: Includes games developed for an older set due to the complexity of the game (16+).

Game—Children: Includes games developed for children (5+).

Game—Family: Includes dice and word games as well as family standard games (chess, checkers, bingo). Also includes family action and board games. Junior versions of these games belong in either preschool or children game categories depending on the intended audience.

Game—Travel: Includes take-along portable games designed to be played on-the-go. These are games without an LCD screen and are only in game format.

Infant and Preschool Games and Puzzles: Includes games and puzzles developed for children under 5.

Plug N Play: Includes games that must plug directly into either a television, PC (via USB port) or other device for viewing game play. PNP TV viewing game units can either be consoles (base receiver), joysticks or controllers that use built-in proprietary software technology. These games are for entertainment only, learning-based products are found

within the pre-school Electronic Learning category. Video game systems / software are not found within toy product categories.

Puzzles: Includes any puzzle developed for adults and children over 5 years of age. (Toy Industry Association, 2013, p. 3)

As mentioned in the last section, games and puzzles belong to the closed-ended toy due to the single purpose and restricted rules.

2.3.3.10 Infant Toys

Bath: Includes toys developed for use in the bath for kids under 3 years of age.

Electronic Learning: Includes electronic learning toys created for kids up to 3 years of age.

Mobiles: Includes all types of mobiles that hang over an infant's crib, playpen or carriage.

Other Infant Toys: Includes all other infant toys that are not classified within any other infant class (activity mirrors, stacking blocks, puzzles, squeeze toys).

Play Gyms, Mats and Nests: Includes all types of play gyms, mats and nests that have basic activity play for infants. Also includes soft play mats, infant play tunnels and play quilts intended for infants.

Plush: Includes plush developed for infants (up to 3 years of age).

Rattles, Toy Pacifiers, Toy Teethers: Includes all toy rattles, toy pacifiers and toy teethers. Non-toy or functional teethers and pacifiers are excluded from this category.

Jumpers and Walkers: Includes infant items that have activity play in addition to wheels that can covert the toy to allow for walking. Also includes walkers that convert to a ride-on, walkers within an electronic learning component, and jumpers with activity play or an electronic learning component. (Toy Industry Association, 2013, p. 4)

According to Piaget's theory, for children from birth to 2, sensorimotor play dominates the stage. The use of the sensorimotor toys is fully defined by designers, whether it's designed for infants to hear, to bite, to squeeze, to stretch, etc. So infant toys are all closed-ended.

2.3.3.11 Miscellaneous

All Other: Includes a wide range of toys that are not included in any of the individual categories, such as working powered appliances and food mixers, spinning tops, yo-yos, pinwheels, banks, marbles, jacks, sponge balls, punch balls, non-collectible stickers, colorforms, etc.

Designer Art/Urban Vinyl Toys: Includes collectible figures and other toys, often based on pop culture or art intended for teens and adults.

Magic Activities: Includes toys that involve the use of magic.

Novelty: Includes lower-priced toys developed for kids of all ages, may often be licensed and reside near a check-out counter.

Projectors / Viewers and Accessories: Includes toys which allow children to view images of varying characters through projection reels. This does not include projection items that allow kids to draw.

Religious: Includes toys that have a religious theme or component. (Toy Industry Association, 2013, p. 4)

Most of the miscellaneous type of toys are closed-ended. Design art/urban vinyl toys are mostly for hobby collection; magic activities toys are designed to play magic only; projector/viewers toys only have single function; the serious religious toys are also not designed to play with an open-ended way. However, some toys in this type are open-ended, such as marbles, sponge balls, and etc. The play rules of these toys are defined by players which means they can become either open-ended or closed-ended.

2.3.3.12 Models

Models: "Includes kits where a child builds a replica of varying types. The child either glues together or snaps individual pieces into an item which is not intended to be taken apart" (Toy Industry Association, 2013, p. 5).

Model toys are not intended to be taken apart, which means they are single-use toys. So they are not open-ended.

2.3.3.13 Musical Instruments and Toys

Musical Instruments and Toys: "Includes instruments that are junior-sized or full-sized with which the child can create their own music. Also includes musical toys for kids ages 5+" (Toy Industry Association, 2013, p. 5).

Musical instruments are designed to learn and create music without any other purpose. They are closed-ended. But musical toys can be used as a component with other toys in the symbolic play, which can be open-ended.

2.3.3.14 Outdoor Seasonal Toys

Banners, Kites and Windsocks: Includes banners, kites and windsocks that are meant for outdoor use.

Bubble Solution and Playsets: Includes all bubble making toys and solutions, as well as accompanying playsets.

Lawn and Gardening Sets and Tool Kits: Includes items developed for use by children that mimic adult lawn and gardening sets and have real use. Items meant for role-play would not be classified in this category; rather, they would be categorized in the infant and / or preschool categories.

Playground Equipment: Includes all outdoor gym centers, swing sets, trampolines, sand boxes, water tables and picnic tables made for children. Also includes children's outdoor patio and beach furniture. Some of these items can be used indoor as well, such as ball pits, beach tents, etc.

Pools, Water and Sand Toys and Accessories: Includes kiddie swimming pools that are not made with steel frames, are not sold with any pumps or filters, and cost up to $150. Includes all toys designed to be played in a pool or at the beach, as well as toys meant to

be played outside with water such as sprinklers, slip and slide, etc. Does not include water blasters or outdoor water boxes / sand tables.

Water and Other Blasters: Includes water and other blaster toys that are intended for use outdoors (may also have an indoor use function). (Toy Industry Association, 2013, p. 5)

Most of the outdoor seasonal toys are closed-ended. Banners, kites and windsocks are intended to be played in a single way on a windy day; lawn and gardening toys are intended to teach children how to operate a real machine rather than open-ended pretend play. Playground equipment has a different design sequence compared to typical toy design, which is hard to involve in the same design approach, while some toys such as sand toys are still open-ended, which is great for pretend play.

2.3.3.15 Plush

Infant: Includes plush developed for infants (up to 3 years of age).

Puppets: Includes all puppets that can be put on a child's hand or finger.

Special Feature: Includes plush toys that are battery powered or have a computer chip so that the toy can, walk, talk, sing, laugh, dance or interact with a child.

Traditional: Includes plush toys for ages 3+ that have no special feature or characteristic. This includes character shaped pillows or play faces. (Toy Industry Association, 2013, p. 6)

Plush toys are all open-ended toys. Children can play with plush in their own ways. But again, because the children in the sensorimotor stage are not able to play in an open-ended way, plush toys for children under 2 years old are closed-ended.

2.3.3.16 Preschool Toys

Bath Toys: Includes toys developed for use in the bath for kids ages 3 to 5.

Electronic Learning: Includes electronic learning toys created for kids ages 3 to 5.

Figures Play sets and Accessories: Includes figures and play sets that are geared toward preschool children. Add-on items for play sets are in this category, as well as items those are sold separately but can be used for play within the play set.

Kitchen and Food: Includes all items that center around pretend play in a kitchen, grocery store, restaurant and supermarket. Includes pretend kitchen sets, food, pots, utensils, dinnerware, picnic related items and cash registers.

Learning: Includes all non-electronic items that have a basic learning function that are intended for preschool children.

Musical Instruments: Includes play musical instruments that are created for use by preschoolers. They may or may not have some type of recorded music, but do allow the child to play and create sounds.

Other Toy: Includes all preschool toys that do not fit into the other categories of toys designed for children between ages 3 and 5. Some examples include: preschool blocks, playhouses, play tents and tunnels, indoor rocking toys, etc.

Other Role Play: Includes all items for pretend play that are not centered on food, including doctor sets, gardening, construction, laundry, cleaning, camping, etc. Dress-up items are not included in this category.

Push & Pull: Includes all toys that involve either a "pushing" or "pulling" action as part of the play pattern.

Talking and Sound: Includes all preschool toys that have a talking and sound feature designed for fun play. The electronic feature is programmed into the toy. These items are not learning toys. (Toy Industry Association, 2013, p. 6)

Most preschool toys belong to open-ended toys. The learning toy, as presented earlier, is close-ended. Musical instruments were also discussed earlier, which can be either open-ended or close-ended. Toys in other sub-types are all not fully defined for how to use and are open-ended toys.

2.3.3.17 Ride-Ons

Non-Pedal Ride-Ons: Includes seated ride-ons where there is no pedaling action for motion; instead, the ride-on is powered by the child (non-electrical). Includes wagons and balance bikes. Skates, scooters, and skateboards are included in Sports Toys.
Pedal Ride-Ons: Includes tricycles and other ride-on toys in which the child uses pedals to set the ride in motion. Does not include children's bicycles.
Powered Ride-Ons: This category includes ride-ons that are powered by battery for movement. (Toy Industry Association, 2013, p. 7)

Ride-on toys are all closed-ended because the way of use is fully defined.

2.3.3.18 Sports Toys

Balls, Games and Sports Activities: Includes sport-related activity items and games intended for children. Toy sporting equipment and all sizes of sports balls are included here.
Skates / Scooters and Skateboards: Includes all skates, scooters (stand-up) and skateboards for children. The item may be powered by the child or have a motor for movement.
Winter Sport Toys: Includes all types of sport toys that are developed for use in the snow. (Toy Industry Association, 2013, p. 7)

Sports all come with strict rules. So, all the sport toys are closed-ended.

2.3.3.19 Vehicles - Powered

Electric Train Sets: Includes any kind of electric train that runs on a track.
Friction / Pump / Pull-Back, Electric and Battery Vehicles: Includes any vehicle that is powered via pull back, friction, rubber band, rip cord or air / water pump or use a battery for movement (without a remote control). The scale does not matter.
Playsets and Accessories (for Powered Vehicles): Includes any kind of racing set for powered vehicles that includes a racetrack and is powered by electricity or by battery. The speed is controlled by a transformer.

Radio/RC Aircraft, Boats, Cars, Trucks and Planes: Contains all items that are set in motion through the use of a remote controller for kids ages 5+. This would also include RC Kits for assembly. (Toy Industry Association, 2013, p. 7)

Powered vehicle toys are analyzed together with non-powered toys in the next sub-section.

2.3.3.20 Vehicles- Non-Powered

Aircraft, Boats, Cars, Trains, Trucks and Planes: Includes all vehicles that are non-powered for movement.

Finger / Extreme Vehicle: Includes any type of finger sport item such as a skateboard, fingerboard, bike, scooter, etc. that is small and controlled by a child's finger.

Mini Vehicles: Includes any vehicle that is not powered for movement in any way and is less than 4" in size. They may have light and sound.

Play sets and Accessories (for Non-Powered Vehicles): Includes play sets for vehicles such as airports, garages and police stations. Any type of track set for a non-powered car (friction powered vehicles can move on the sets). The main feature of the item is the play set although vehicles may or may not be included. (Toy Industry Association, 2013, p. 8)

Not like ride-on vehicles, these two types of toys (powered and non-powered vehicles) are not for children to fit into. The feature of the size makes it easier for children to handle. "As well as changing scale, most toys are simplified transformations of the objects they represent, and often this fact that they suggest rather than replicate the original is the strongest characteristic of toyishness that they have" (Newson & Newson, 1979, p. 120). Children are able to fit the vehicle toys in any other toys that they have and create the pretend play together. So, all the vehicle toys are open-ended.

2.3.3.21 Youth Electronics

> **App-Enabled, Interactive Playmates or Robotics:** Includes high tech toys or "appcessories" where a physical toy interacts with a smartphone, tablet or gaming device. Also includes high tech toys that interact with a child or battle with similar toys. Toys can be shaped as robots, animals, vehicles and other creatures.
> **Electronic Entertainment:** Includes items that are working devices that mimic adult electronics (CD player, DVD player, camera, cell phone). (Toy Industry Association, 2013, p. 8)

As indicated earlier, the app-based electronic toys are closed-ended toys. Electronic entertainments like CD players are serve as tools for playing the carrier, whether they are music or movie. So, they are also closed-ended.

2.3.3.22 Summary Tables of the Toy Types

Category	Sub-category	Open-ended (Green)/ Closed-ended (Red)	Involved (Y/ N)	Reason
Action Figures	Action Figures, Playsets and Accessories		Y	
	Role Play (non-costume)			
Arts and Crafts	Chalk, Crayons, Markers Paints and Pencils		Y	
	Reusable Compounds (e.g., Clay, Dough, Sand, etc.) and Kits			
	Design Kits and Supplies – Reusable			
	Design Kits and Supplies – Single Use		N	Single use
Battling Toys	Battling Toys, Playsets and Accessories		N	Function Fully Defined
Building and Construction	Building Sets and Accessories		Y	
Collectible Trading Cards and Toys	Collectible Trading Cards		N	Function Fully Defined
	Collectible Trading Toys and Accessories			
Costume and Dress-Up	Costume and Dress-Up and Accessories		N	Function Fully Defined
Dolls	Display Dolls and Accessories		N	Function Fully Defined
	Dollhouses and Accessories		Y	
	Fashion and Styling Dolls, Play sets and Accessories			
	Mini, Figurines and Playsets and Accessories			
	Nurturing Dolls and Accessories			
Educational	Electronic Learning Systems (for 5+)		N	Function Fully Defined
	Infant- Electronic Learning			
	Preschool Electronic Learning			
	Maps, Globes, etc.			
	Science			
Games & Puzzles	Brainteasers		N	Function Fully Defined
	Cards – Basic			
	Cards – Strategic Trading			
	Electronic Handheld / Tabletop Games			
	Game – Adult			
	Game – Children			
	Game – Family			
	Game -- Travel			
	Infant and Preschool Games and Puzzles			
	Plug N Play			
	Puzzles			

Table 2. 5 Summery of toy types 1

Category	Sub-category	Open-ended (Green)/ Closed-ended (Red)	Involved (Y/ N)	Reason
Infant Toys	Bath		N	Function Fully Defined
	Electronic Learning			
	Mobiles			
	Other Infant Toys			
	Play Gyms, Mats and Nests			
	Plush			
	Rattles, Toy Pacifiers, Toy Teethers			
	Jumpers and Walkers			
Miscellaneous	All Other		Y & N	Either Open-ended or Closed-ended
	Designer Art/Urban Vinyl Toys		N	Function Fully Defined
	Magic Activities			
	Novelty			
	Projectors / Viewers and Accessories			
	Religious			
Models	Models		N	Single use
Musical Instruments and Toys	Musical Instruments and Toys		Y&N	Either Open-ended or Closed-ended
Outdoor Seasonal Toys	Banners, Kites and Windsocks		N	Function Fully Defined
	Bubble Solution and Playsets			
	Lawn and Gardening Sets and Tool Kits			
	Playground Equipment		N	Different Design Approach
	Pools, Water and Sand Toys and Accessories		Y & N	Either Open-ended or Closed-ended
	Water and Other Blasters			
Plush	Infant		N	Function Fully Defined
	Puppets		Y	
	Special Feature			
	Traditional			
Preschool Toys	Bath Toys		Y	
	Electronic Learning		N	Function Fully Defined
	Figures Play sets and Accessories		Y	
	Kitchen and Food		Y	
	Learning		N	Function Fully Defined
	Musical Instruments		Y & N	Either Open-ended or Closed-ended
	Other Toy		Y	
	Other Role Play			
	Push & Pull			
	Talking and Sound			

Table 2. 6 Summery of toy types 2

Category	Sub-category	Open-ended (Green)/ Closed-ended (Red)	Involved (Y/ N)	Reason
Ride Ons	Non-Pedal Ride-Ons		N	Function Fully Defined
	Pedal Ride-Ons			
	Powered Ride-Ons			
Sports Toys	Balls, Games and Sports Activities		N	Function Fully Defined
	Skates / Scooters and Skateboards			
	Winter Sport Toys			
Vehicles - Powered	Electric Train Sets		Y	
	Friction / Pump / Pull-Back, Electric and Battery Vehicles			
	Playsets and Accessories			
	Radio/RC Aircraft, Boats, Cars, Trucks and Planes			
Vehicles- Non-Powered	Aircraft, Boats, Cars, Trains, Trucks and Planes		Y	
	Finger / Extreme Vehicle			
	Mini Vehicles			
	Play sets and Accessories			
Youth Electronics	App-Enabled, Interactive Playmates or Robotics		N	Different Design Approach
	Electronic Entertainment			

Table 2. 7 Summery of toy types 3

As Table 2.5, Table 2.6, Table 2.7 shown, all the toy types have been analyzed and determined if they are suitable to be included in the scope of design method development. The first and second columns are the toy categories and sub-categories defined by the Toy Industry Association. The third column stands for if the sub-category belongs to open-ended or closed-ended toy category based on the discussion earlier. Red is closed-ended; green is open-ended; grey is either closed-ended or open-ended. The fourth and fifth columns indicate whether this type of toy will be involved in the research scope or not and the reason why it's not involved.

2.4 Principle of Modularity

In this section, the concept of module, modular and modularity will be introduced; existing concepts and viewpoints in product modularity and modular system will be presented; the relationship between modularity and child development as well as open-ended toy will be discussed.

2.4.1 Definition of Module and Modularity

A module can be defined as a changeable part that provides a considerable amount of functionality compares to the final product (Miller & Elgard, 1998). It is emphasized that the function unit that a module holds is self-contained, which means by switching the installed module, one can easily modify the functionality that the whole product has. So, one module always has a system behind it. The system has standardized interfaces and interactions that allow to make composite products through different combinations.

> Modularity is an attribute of a system related to structure and functionality. A modular structure is a structure consisting of self-contained, functional units (modules) with standardized interfaces and interactions in accordance with a system definition. Replacing one module with another creates a new variant of the product. (Miller & Elgard, 1998, p. 16)

2.4.1.1 Module & Block

The comparison between the concept of module and block has been argued frequently in related research. Miller and Elgard (1998) explained the difference between these two concepts

by giving an example of Lego blocks. They indicated that Lego blocks belong to building blocks rather than modules, although they do have a standardized interface allowing infinite combinations. It is because each piece does not possess any amount of functionality.

Huang (2000) proposed a similar but not exactly the same idea about these two concepts. He introduced the thought of functional and physical elements. “The functional elements of a product are the individual operations and transformations that contribute to the overall performance of the product. The physical elements of a product are the parts, components, and subassemblies that ultimately implement the product functions” (p. 150). The building blocks stand for the physical elements that organize the product. If a block is a collection of interchangeable components that contains a number of functions, this block is a module.

2.4.1.2 Modular Structure vs. Integrated Structure

The concept of module brought out the system of modular structure, which is opposed to the traditional integrated structure. “In a modular structure, a module implements only one or a few main functions in its entirety, whereas in an integral structure, the functionality is spread all over the product” (Miller & Elgard, 1998, p. 6).

Huang (2000) stated that integrated architecture should have one or more properties as follow: the functional elements of a product correspond to several blocks; one block may contain several functional elements; the interactions between blocks are ill-defined and may be incidental to the product’s primary function. Some requirements from customers such as the ability for upgrading, adding-on, adapting, reusing, and etc. promote the development of modular structure,

because modules allow changes to be made to isolated functional elements of a product without necessarily affecting the design of other elements' functionalities. However, in a traditional integrated structure, the changing of one block may influence many functional elements and require changes to several related blocks.

Integrated architecture	Modular architecture
A collection of components that implement some functions of a product is called a block.	A collection of components that implement some functions of a product is called a module.
The functional elements of a product are implemented using more than one block.	Same as an integrated architecture.
A single block implements many functional elements.	A module implements one or a few functional elements in their entirety.
The interactions between blocks are ill-defined and may be incidental to the primary functions of the products.	The interactions between modules are well defined and are generally fundamental to the primary function of the product.
Product performance can be enhanced through an integrated architecture.	Product performance may not be enhanced by an modular architecture.
Changing a block in an integrated product may influence many functional elements and require changes to several related blocks.	Changing a few isolated functional elements of a product may not affect the design of other modules.

Table 2. 8 The Comparison of Modular and Integrated Architectures (Huang, 2000)

Huang (2000) made a table (Table 2.8) for comparing the modular and integrated architectures from different perspectives based on the opinions from previous research conducted by Ulrich and Eppinger (1995).

2.4.1.3 Modularity types

According to Kamrani and Salhieh (2000), modularity can be applied in three main areas, which is product design, design problem, and production system.

> Modular products are products that fulfill various overall functions through the combination of distinct building blocks or modules, in the sense that the overall function performed by the product can be divided into sub-functions that can be implemented by different modules or components. (Kamrani & Salhieh, 2000, p. 20)

The application of design problem modularity is breaking a massive problem down into a set of easier-to-solve sub-problems. After the overall problem is divided into functionally independent sub-problems, the interaction or interdependence between sub-problems is minimized and becomes easier to manage.

Modularity in production systems aims at "building production system from standardized modular machines" (Kamrani & Salhieh, 2000, p. 20). Four basic groups of production elements need to be considered in order to achieve production system modularity. These are process machine primitives, motion units, modular fixtures, and configurable control units.

2.4.2 Product Modularity

2.4.2.1 Types of Function Modules

Roozenburg (1995) identified the function modules and production modules as two important module types in composing a modular system. Function modules are designed to accomplish technical functions independently or in combination with other modules. Production modules are designed based on production considerations alone and are independent of their function. Function modules are designed to have the ability to accomplish the certain tasks or functions independently. Production modules are designed based on production requirements and are independent of their function.

Pahl and Beitz (1996) suggested five function module types based on the different functions that the module provides. These functions are basic, auxiliary, special, adaptive, and

customer-specific functions. They are implemented by basic modules, auxiliary modules, special modules, adaptive modules, and non-modules. (See Figure 2.3)

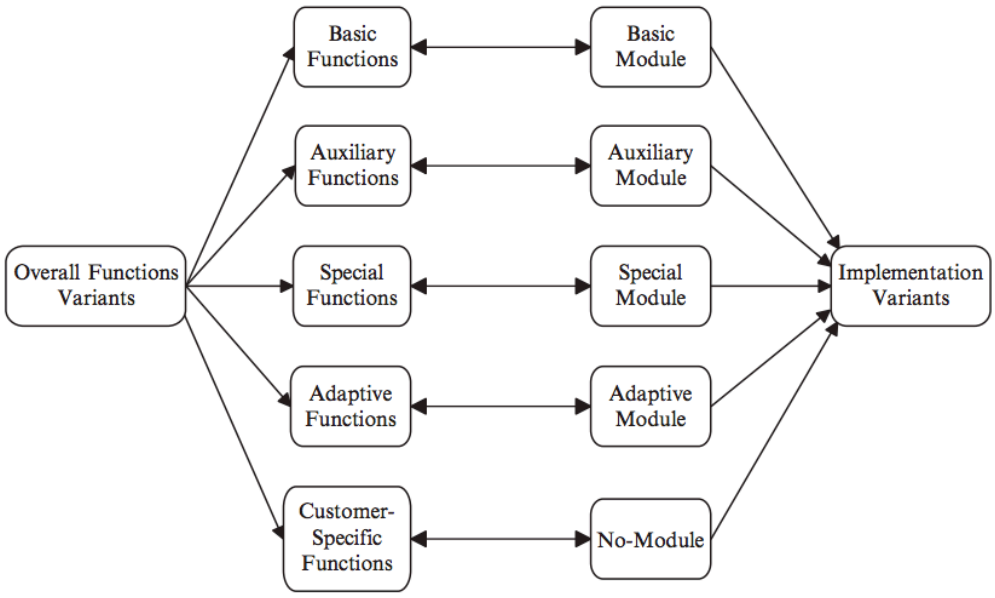

Figure 2. 3 Function and Module Types

Basic functions are simple, non-variable functions that are fundamental for the product or system. Auxiliary functions are implemented by auxiliary modules, which are used in conjunction with the basic modules to create variable products. Special functions are task-specific sub-functions that may not appear in all overall function variants. Adaptive functions can permit the adaptation of a part or a system to other products or systems. Customer-specific functions are non-modules that are designed individually for meeting the specific tasks (Pahl & Beitz, 1996; Kamrani & Salhieh, 2000; Huang, 2000).

2.4.2.2 Approaches to Product Modularity

Not like defining the module types by differentiating functions that Pahl and Beiz provided, Ulrich and Tung (1991) presented five modularity approaches based on the module interactions and combinations within the product. These are component swapping modularity, component sharing modularity, fabricate-to-fit modularity, bus modularity, and sectional modularity. Miller and Elgard (1998) share a figure to illustrate these approaches.

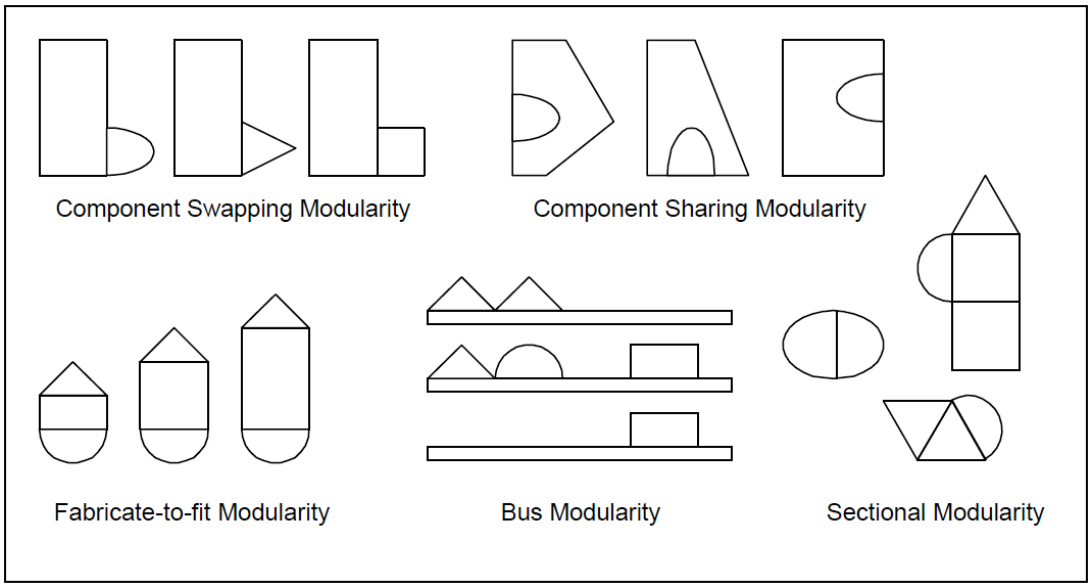

Figure 2. 4 Five Approaches to Product Modularity from Ulrich & Tung (1991)

Component Swapping Modularity represents the different product variants for the same product family. This occurs when two or more different basic components can be paired with one module. Component Sharing Modularity represents the different product variants for different product families. This occurs when one module can be fitted in two or more different basic components. Fabricate-to-fit Modularity represents that one or more standard modules that can be paired with one or more infinitely variable basic components. Variation is usually associated

with physical dimensions that can be modified, such as a set of charging cables with different length. Bus Modularity represents that one module can be matched with any numbers of basic components. “Bus modularity allows for variation in the number and location of basic components in a product while component-swapping and component-sharing modularity allows only for the types of basic components to vary” (Huang, 2000, p. 151). Sectional Modularity represents the modular model that all basic components are serving as modules and the product are merged with different basic components combinations without a fixed module.

2.4.3 Modular System Development

Kamrani and Salhieh (2000) indicated an approach for developing modular system. They listed three steps, “decomposing a system into its basic functional elements, mapping these elements into basic physical components, then integrating the basic components into a modular system capable of achieving the intended functions” (p. 25). And two challenges, decomposition and integration, were emphasized to be vital in this approach.

2.4.3.1 The Concept of Decomposition

The term decomposition mentioned in this research is focusing on decomposing the massive product, function, and problem into more easily solvable ones. By utilizing decomposition, one can achieve the system simplification and accelerate problem-solving. According to Kamrani and Salhieh (2000), the decomposition method can be applied in product decomposition, problem decomposition, and process decomposition. Process decomposition is

the decomposition of the entire design process, which is unnecessary to talk about in this research, so it will not be developed further.

Product decomposition contains two approaches, product modularity and structural decomposition. Product modularity represents the independent physical components that have similar functional and physical characteristics. It relies on the lack of dependency between the physical components. Structural decomposition represents the product which has a hierarchical structure that can be decomposed step by step, from one main body to functional structures, then to sub-functional structures, etc.

Problem decomposition can be divided into requirements decomposition, constraint-parameter decomposition, and decomposition-based design optimization. Requirements in the first category represents an abstraction of design problems. Decomposition starts with determining overall requirement and ending with the specific requirements in a tree-diagram. Constraint parameter decomposition is associated with the decomposition of the incidence matrix. Decomposition-based design optimization is decomposing a large complex design problem into smaller independent sub-problems by using mathematical programming technique and optimizing the sub-problems (Kamrani & Salhieh, 2000).

2.4.4 Benefits of Modularity

Miller and Elgard (1998) stated that modularity could be seen as a means to balance two opposite forces: standardization and customization. Starting from these two aspects, researchers

discovered many benefits that modularity provides (Ulrich & Tung, 1991; Pahl & Beitz, 1996; Huang, 2000; Kamrani & Salhieh, 2000).

Economies of scale: Since the standard modules will usually be manufactured in relatively large quantities, the economies of scale arise.

Ease of product maintenance and repair: Since the product can be decomposed to several independent single modules, just replacing the modules can easily achieve maintenance and repir.

Decrease order lead-time: Modular products always consisted of standardized and customized components. Once the modular system is formed, standard components are inventoried, and then customization can be focused on differentiating components. This will support the company's fast response and lead to reduction in order lead-time.

Reduce product-developing time: Since the interfaces and modules have been standardized, their interfaces enable design tasks and production tasks to be decoupled. This decoupling will eventually result in the reduction of the product-developing time.

Increase feasibility of product/component change and upgradability: Since each module interface is strictly defined, it is obvious that each module is independent, which means changing components and upgrading is relatively much simpler.

Increase feasibility to meet customer needs: The module system is made with a combination of several standardized and customized components. Manufacturers can always develop customized modules to meet individual needs.

Miller and Elgard (1998) presented three basic drivers behind the wish for modularity: creation of variety, utilization of similarities and reduction of complexities. These drivers are corresponding to the different benefits that modularity provides (See Figure 2.5 below).

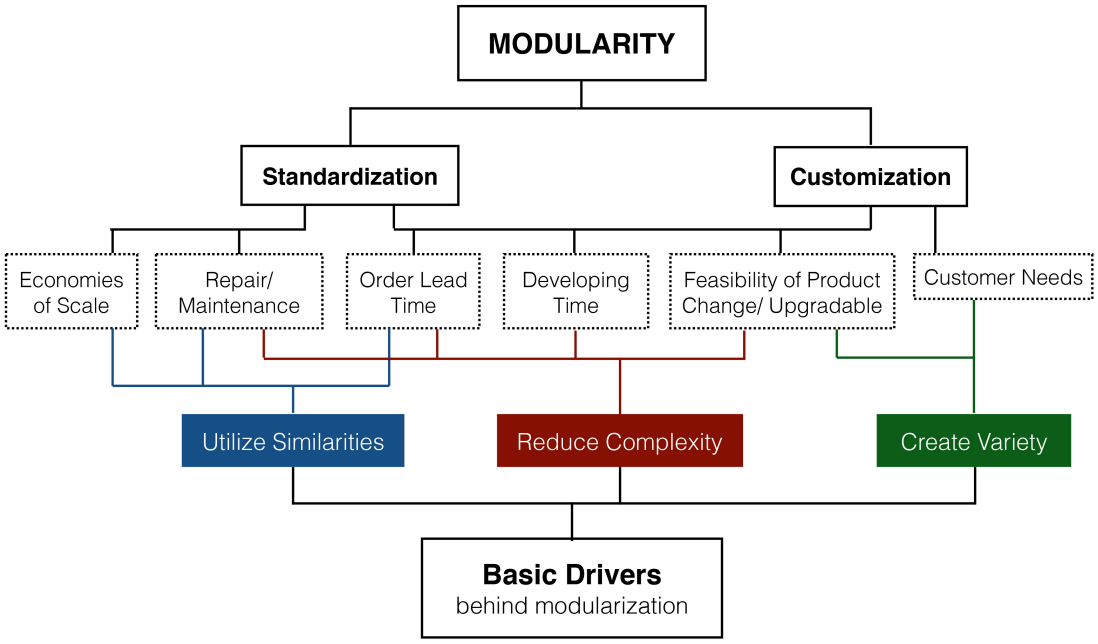

Figure 2. 5 Relationships of the Benefits of Modularity

2.4.5 Modularity, Children Development & Open-ended Toys

As we indicated earlier, the functionality of toy is play. Different toys provide different play experience. Dolls and doll houses give children the chance to have make-believe play with easily controlled story lines, because they can develop the story based on what they experience in their daily life; educational toys help children to learn the knowledge spontaneously through play. Wooden blocks present a more open-ended way of playing; they can serve as constructive

toys for building a skyscraper or a supercar, or be used for mathematical educational purpose like counting.

As children grow up, they need more toys. It is not only because they are bored with the old so they need to be stimulated by new toys, but also because of the requirement of the different needs in different child development stages. The development stages, as discussed earlier, have three aspects, which are cognitive development, social development, and motor development. For meeting the new needs, toys need to provide the corresponding functions. So, selling new toys with new functionalities seems to achieve this goal flawlessly, while, actually it's not. From one point, toy waste is increasing dramatically due to short-term and disposable toys; from another point, toys are not "the more the better". Research from the University of Toledo suggested that too many toys may debase the quality of play for children (Dauch, Imwalle, Ocasio, & Metz, 2018). Because children need to spend more time with one toy in order to release the full potential that this toy holds, too many toys will make children spread the time equally on different toys, "lazily" observing rather than exploring, which will not benefit the development of children.

In this case, children need fewer but better toys to play and explore. One of the most important virtues that the "better toy" needs to have is the play potential. This means that toys need to have the ability to be discovered and create as many play methods as possible. So, closed-ended toy, as the play that this type of toy provides have been strictly defined, will not be appropriate to be developed in this research. Closed-ended toys are not defined as less useful or

less important than open-ended toys. As discussed in earlier, both open-ended and closed-ended toys have their own role in children's play worlds and children development.

Applying modularity to toy design will make it possible for toys to grow-with-the child. If the modular product system was well designed, updating new modules with advanced functionalities to the basic component can greatly increase the life of a toy from the usability stand point. And these newly applied modules need to reflect the needs of children in an older age group, which refers to the considerations of children's cognitive, social, and motor development. Toy modularity can also solve the problems stated earlier caused by the unplanned massive toy production, toy waste and toy distraction.

Chapter 3 Case Study

In this chapter, cases will be studied for exploring and analyzing existing design solutions. Strategies will be extracted from these selected cases.

3.1 Block Toys

3.1.1 The Timeless Qualities

Newson and Newson (1979) presented the idea of "timeless quality" senses of toys. The first kind of toy is the toy which can meet the needs that children have always had, including "to explore, to invent, to create, to test out their skills, to show off, the stretch their physical limits, to fantasize, to role-play and to act protectively to something less powerful than themselves" (p. 69). The second kind of the toy is the toy which is able to grow through time with the child, which makes the function of toy remain valid for over a very long period of childhood. And the toy can be used by the child in ways that reflect the stage he or she has reached in growing up.

Three types of timeless toys were given as examples in their book: "big-muscle" toys for physical play, blocks, and dolls. "Big-muscle" toys mainly serve as big play equipment for outside use. According to the conclusion in the "Toy Type" sub-chapter, this type of toy will not be included in this research. Block toys will be analyzed in the following paragraph.

3.1.2 Analysis of Block Toys

In the toy type lists given by Toy Industry Association (2013), block-like construction toys like LEGO were differentiated from the traditional age-appropriate block toys. So, in this section, the building and construction toys with standardized self-locking interfaces will not be discussed.

According to Rybczynski (1993), the earliest mention of building block toys appeared in Maria and R.L. Edgeworth's Practical Education. They are called "rational toys" that are able to teach children about gravity, physics, and the relationship between part and whole.

Block toys are suitable for children to play with from twelve months to twelve years; "they probably have the longest life of any toys" (Newson & Newson, 1979, p. 84). Children at different ages can play with block toys in different ways. If a boy is enthusiastic about playing vehicle toys, he can make a toy car when he is 2 years old; he can build a bridge at 3; he can build the roadway layout for Matchbox when he is 4; he can even structure the underlying road system at 7. During the development of this boy, he is able to build more and more complex and sophisticated things. As presented earlier, this belongs to the first timeless quality: meeting the need that children always have, to explore, to invent, to build up things in their mind.

The block toy designed by H.G. Wells has some built-in mathematical properties; the length is twice the width and the width is twice the thickness. These properties maximized the possibilities of combination varieties during play. In this case, the designed shape has given children enough freedom to express their imagination and explore the built-in mathematical

thinking. Children are able to develop the imaginative play by taking advantage of these ratios, which makes the play neither totally free nor fully defined.

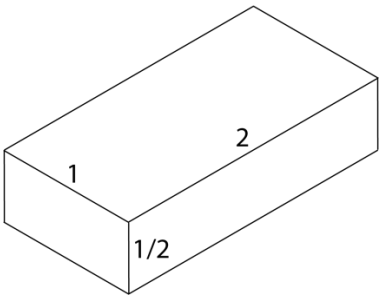

Figure 3. 1 Illustration of H.G. Wells's Block Ratio

Block toys can also be designed towards the closed-ended style. Taksa Toys developed a block toy series called Arch•Kid•Tech. This series is aiming at teaching kids to learn to build some fantastic building structures from the ancient era. Similar to this series, the architecture building block toys in HABA Toys also provide the follow-the-instruction play approach. Though the instructions in these two toys may lead initial toy play to look like closed-ended play, the children are able to explore more interesting structures or architectures by using their imagination and creativity after they have mastered the instructed playing approaches.

Figure 3. 2 Arch•Kid•Tech from Taksa & Archetecture Blocks from HABA

We can see that although the H.G. Wells's block as well as the structure learning block toy all belong to one toy type, different designs lean towards to the consideration of different development areas. H.G. Wells's blocks focused more on developing mathematical thinking during imaginative play; the structure learning blocks emphasized more instruction following, fine-muscle controlling, and the learning of structure stabilization. This suggest that the design approach developed in this thesis needs to consider different design tendencies, whether towards more to free play or closed-ended play; more to cognitive development aspects such as imagination, problem-solving or to social and motor development aspects. No toy can dominate the market because they have different functions for providing different needs. (Mergen, 1982) This also means that no toy can hold universal functions. In order to emphasize the design in one particular area, other areas will be neglected. It is designer's choice to decide which area that the design emphasize. And providing the chance for designer to make different choices is one significant aspect that needs to be involved in the developing of the design approach.

3.2 LEGO

Lego toys belong to the building and construction toy category, which includes interlocking pieces that can be taken apart and allow for building in multiple ways. The powerful standardized interlocking system that Lego developed allows children to achieve infinite building outcomes with only one set. Moreover, it allows different sets to fit together for building a more complex creation. Figure 3.3 shows two examples of multiple Lego building sets fitting together.

Figure 3. 3 Examples of the Outcomes of Multiple Lego Building Sets

As stated in the early chapter, individual building blocks such as Lego bricks cannot be seen as module because of the lack of self-contained function. However, because of the standardized interlocking system, every piece in different sets can be joined together, in which case each set can be seen as module.

The interlocking system not only includes the standard size bricks which are designed for children four years of age and up, but also contains the much bigger bricks in the earlier age group. Lego Duplo is a product range designed for children age 1 to 5 years old. It's twice the length, height and width of traditional Lego bricks, making it easier to handle and less likely to be swallowed by younger children ("Building with LEGO and DUPLO bricks", 2018). Lego Duplo was designed to be compatible with traditional Lego bricks (See Figure 3.4). It is possible to build things by utilizing the bricks in both types. In the building demonstration in Figure 3.5, the foundation of the structure was built by using Duplo bricks and the appearance was built by using regular Lego bricks (Jangbricks, 2015). As the Duplo bricks serve the function of saving materials, they can be treated as a module.

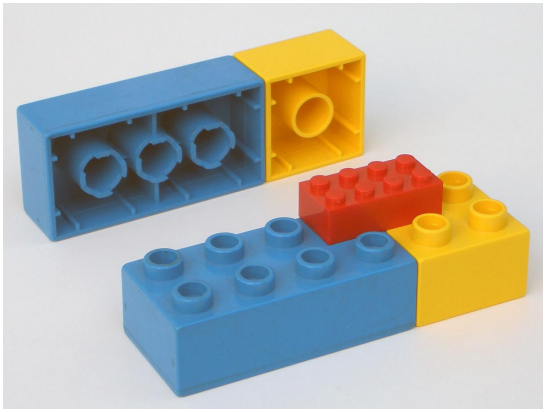

Figure 3. 4 Demonstration of Duplo and Traditional Lego Brick Compatibility

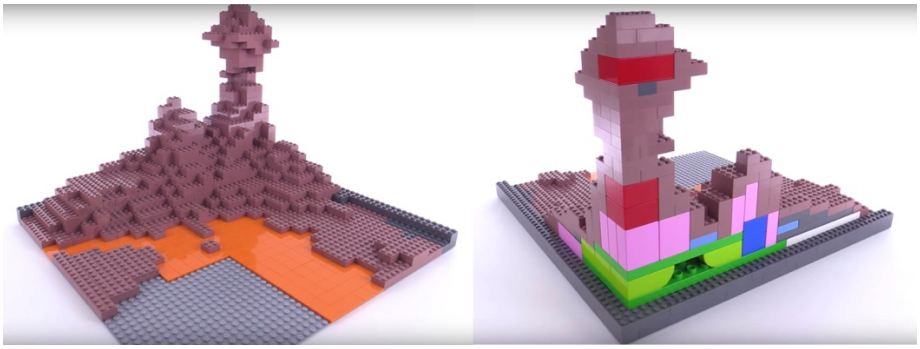

Figure 3. 5 Building Demonstration of Duplo with Traditional Lego Brick (Jangbricks, 2015)

The design behind the Duplo bricks utilizes the idea that in a modular product system, a later stage product or module can be transformed into a new function module for an older stage product, whether keeping or altering the functionality when compared to the initial one.

Chapter 4 Design Approach

This design approach is aiming at extending the toy's serving time by updating or upgrading its functionality. This functionality corresponds to the children's needs in different development stages. Modularity is going to be the tool for designers to achieve toy updatability or upgradability.

The approach can be divided into seven steps: Identify (identifying toy type and age range), Criteria Study (cropping the pre-defined ability development table into defined age range and using it to study the ability distribution in the existing product, selecting abilities), Decomposition (using the result of cropped ability table as a reference to decompose the age range rationally into sub-stages), Concept Generating (using the cross-stage approach and same-stage to generate concepts), Evaluation (grading the abilities in each design, calculating the score in percentage and choosing the final direction), Final Delivery (refining the design and developing final delivery with contains concept tree, ability developing chart and ability distribution chart), and Further Development.

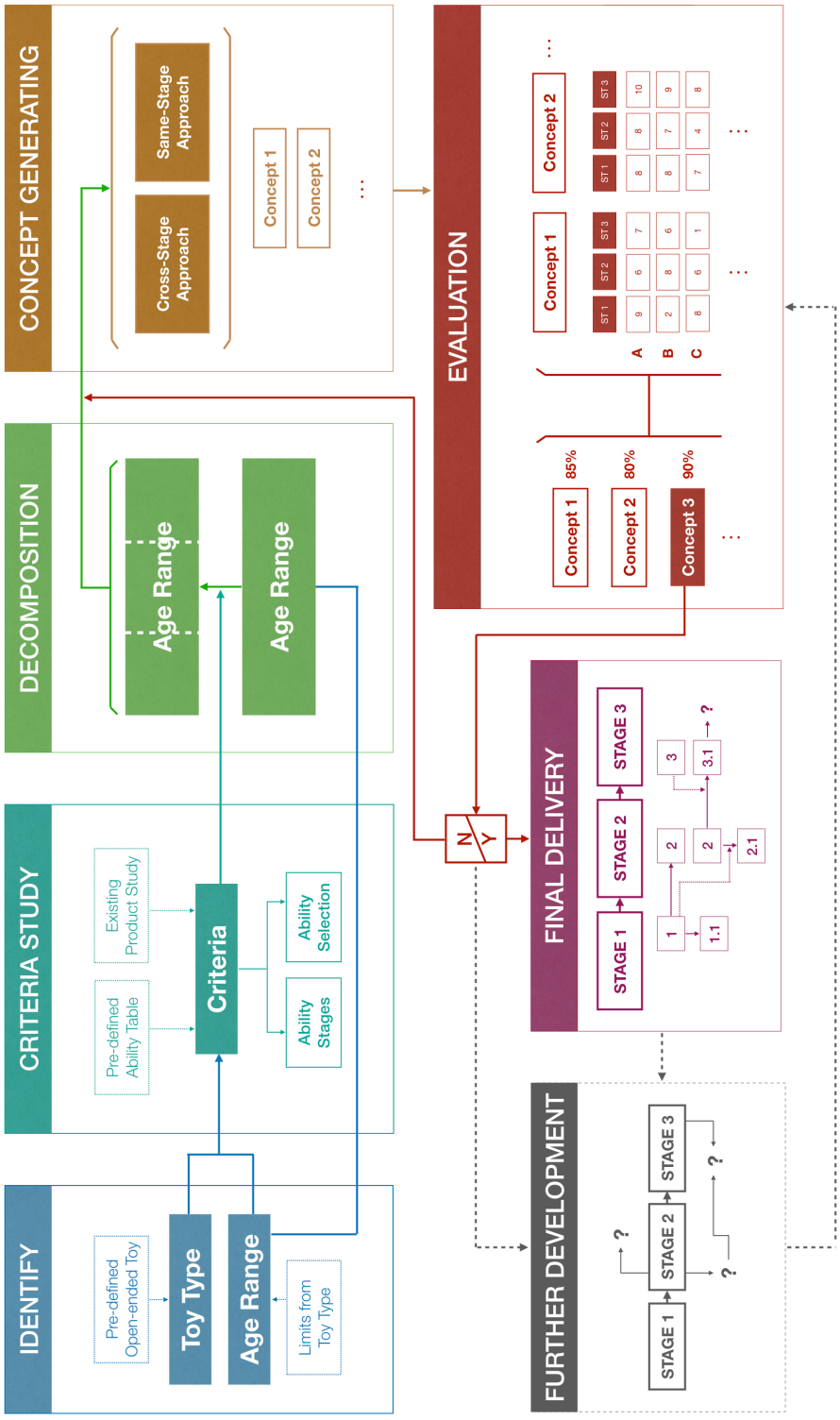

Figure 4. 1 Flow Chart of the Design Approach

4.1 Identify

The very first step of the approach is identifying the toy type and age range. When identifying the toy type, designers need to choose it from the pre-defined open-ended toy type, which has been presented in Table 2.4, 2.5, and 2.6 in the second chapter. After choosing the type, designers then need to define the age range for the whole product system. Some limitations may be given by the certain types of toy, such as the earliest crayon user can be 18 months while the player who are able to play the regular size LEGO bricks safely need to be at least 4 years old.

4.2 Criteria Study

The second step, criteria study, is the step for designers to study the pre-defined ability development table in the selected age range, study the ability distribution of the existing products, and choose the abilities which are going to be involved in the design development.

4.2.1 The Development of the Ability Development Table

With the help of earlier research on play and children development theories, abilities in different periods will be studied. The ability study will be focusing on each ability's development status, which includes undeveloped, developing, rapid developing and developed. Different colors were applied to these four statuses for the table demonstration (see Figure 4.2). Values are also applied to each status for future evaluation: undeveloped got 0, developing got 1, rapid developing got 2, and developed got 3.

Abilities are spread out into three major developmental aspects: cognitive, social and motor development. During the development of the ability table, the easy-to-understand abilities, such as social play in social development, will be studied directly. The hard-to-understand abilities, such as problem-solving in cognitive development, will be further disassembled into several sub-abilities for easy-studying.

Abilities will be studied individually and a summarized ability development table will be generated at the end.

Color				
Developing Status	Undeveloped	Developing	Rapidly Developing	Developed
Value	0	1	2	3

Table 4. 1 Demonstration of Color and Value for Ability Table

4.2.1.1 Cognitive Development

4.2.1.1.1 Imagination & Creativity

Dimensional Comprehension: The comprehension of dimension includes the perception of two-dimensional, two-and-a-half-dimensional, and three-dimensional. It belongs to the spatial perception which means "the ability to be aware of your relationships with the environment around you and with yourself" ("Spatial Perception," 2018, para.1). Research stated that the study of two-dimensional mental rotation tasks has been reliably measured for the children in preschool years with a consistent improvement thereafter (Levine, Huttenlocher, Talor, & Langrock, 1999). Other research proposed that some three-dimensional spatial tests have been

used for improving the spatial skills for children at the age of 5.5 until the late elementary school (Carr et al, 2018). So, it is reasonable to conclude that two-dimensional perception developing is among the children in preschool age group, which is 3 to 5 years of the age; three-dimensional perception developing is among the children from 5.5 years old until late elementary school, 11 to 12 years old. The developing of dimensional perception starts from 3. The most rapidly developing period is from 4 to 7, the period that children have the 2D perception changing to the 3D perception.

Age	3 to 5	5.5 to 11-12
Dimensions Comprehension	2D perception	3D perception

Table 4. 2 Development Stages in Dimensions Comprehension

Age	0-3	3-4	4-8	8-11	11+
Dimensional					

Table 4. 3 Developing Status in Dimensions Comprehension

Dimensional Imagination: Deeply connected with dimensional comprehension, children need to perceive the dimensions in order to express their imagination in different dimensions. It's not necessary for children to fully master the perception skills before they are able to do the imaginative play, instead, dimensional imagination and dimensional comprehension are developing at the same time interdependently. So the developing stages and statuses of dimensional imagination are the same as dimensional comprehension.

Substitution: As presented earlier, substitution emerges into the children's symbolic play and the play dominates the play type during the pre-operational stage (2 to 7). So the development of substitution is following the same sequence as the development of symbolic play. According to Piaget (1962), substitution in symbolic play includes two aspects, object substitution and agent substitution. He also presented three kinds of symbolic play: the first type involves the application of one symbolic scheme to new object, the second type involves one symbolic scheme with substituted object or substituted agent, the third type involves planned combinations of symbolic schemes and a sequence or pattern of behavior which may contain several substituted objects and agents.

Pre-symbolic play, the earliest stage of symbolic play, was observed from 12 months to 2 years of the age (Watson & Jackowitz, 1984). This is also the first stage of substitution. During this stage, the only substitutions are themselves, which means they make self-as-agent with the activities such as pretend drinking and pretend sleeping. The second stage of substitution begins from 18 months to 2 years, in which period Piaget (1962) thought the genuine symbolic play starts to unfold. And this is the second type of symbolic play as presented earlier, one symbolic scheme with substituted object or agent. The third stage is from 2 to 4. It's the time that symbolic play starts to emerge another substituted person, normally would be the mother (Garvey, 1979). The substituted objects are also growing. The last stage is from 4 to 7. From one point, children's symbolic play is transforming from productive play (2 to 4) to reproductive play (4 to 7) (Butler, Gotts & Quisenberry, 1978). Compared to the familiar scheme that used in productive play, the

reproductive play creates more out-of-ordinary schemes. From another point, with the development of children's social ability, the associative and cooperative play starts to emerge. Social-dramatic play is getting more and more popular during this age. The substituted agents vary greatly according to the necessary roles in different symbolic schemes.

Before 1, children are not able to substitute anything. Children's substitution ability dramatically develops from 4 to 7 because of the dynamic range of playing themes. After 7, children are capable of the ability of substitution.

Age	12m to 2	18m to 2	2 to 4	4 to 7
Symbolic Scheme	1 (Familiar)	1 (Familiar)	1 (Familiar)	1+ (Out-of-ordinary)
Agent Substitution	1 (Self-as-agent)	1	1 or 2	1 or 1+
Object Substitution	0	1	1+	1+

Table 4. 4 Development Stages in Substitution

Age	0-1	1-4	4-7	7+
Substitution				

Table 4. 5 Developing Status in Substitution

Approaches & Outcomes: The approach means the different ways that the toy may contain for achieving the same goal. The outcome means the different results the toy can possibly achieve. The approach is focusing on the process while the outcome is focusing on the result. The toy that is emphasizing developing different approaches for the same goal is mostly closed-ended toys such as chess games and sports toys. And the toy that is emphasizing on maximizing the variety of outcomes are open-ended toys such as clay and constructive toys.

Because approaches are mainly designing for complicated closed-ended toys (such as decoding tangram puzzle and Rubik's cube), games and sports, children who are able to play with those toys need to at least master the inductive logic and reasoning ability, which starts to emerge during the concrete operational stage (7 to 11). The toy designed for the earlier pre-operational stage hardly have the approach. Different to the approach, the outcome develops dramatically in the pre-operational stage. Even with the same toy, children at different age group will achieve different outcomes (Newson & Newson, 1979). With children's growth, the symbolic play transforms from productive play (2 to 4) to reproductive play (4 to 7), from meeting their own needs to actually relating to the physical reality. Since the playing goal changes, the outcomes change as well. And the transforming period from 3 to 6 is the period that the outcome ability develops with the highest speed.

Age	2 to 4	4 to 7	7 to 11
Approaches	Low		Developing
Outcomes	Children's need	Physical Reality	

Table 4. 6 Development Stage in Approaches and Outcomes

Age	0-2	2-7	7-11	11+
Approach				

Table 4. 7 Developing Status in Approach

Age	0-2	2-3	3-6	6-7	7+
Outcome					

Table 4. 8 Developing Status in Outcome

Interests & Motivations: Motivation represents the toy's ability of motivating children for imaginative and creative play. And it's greatly connected with children's interests. Children at different ages have different preferences. From 2 to 4, children show more interests in the familiar schemes, such as mom and dad role-play, kitchen pretend play, etc. (Piaget, 1962). From 4 to 6, children would love to step into more roles and play them out in order to better understand these roles. The roles may include doctor, policeman, teacher, and etc. The advanced symbolic play, social-dramatic play, is preferred in this age group. From 6 to 9, children are deeply attracted by sports, games and licensed characters such as superhero and friends themed toys. And from 9 to 12, children's role interest shifts towards to real-life characters such as singer and movie stars while sports and games still occupy most of their entertainment time (Phillips, 2018). Children's interest is changing all the time from 2 years old but there is no sign of intensity changing.

Age	2 to 4	4 to 6	6 to 9	9 to 12
Interests Role	Familiar roles	More unfamiliar roles	Themed characters	Real-life characters
Interests Play	Familiar schemes pretend play	Social-dramatic play	Sports and Games	

Table 4. 9 Development Stages in Interest

Age	0-1	1+
Interest		

Table 4. 10 Developing Status in Interest

4.2.1.1.2 Problem-solving

Convergent & Divergent: Convergent and divergent problem-solving abilities are essential for children development with different purpose. “Convergent problems require children to organize pieces of disparate information to arrive at one correct answer” (White, 2012, p. 12). Divergent problems require children to consider a range of possible solutions rather than one single right answer (White, 2012). Play contributes to children’s problem-solving ability through increasing their behavioral options (Bruner, 1972). So when children come across some real-life problems, they may use the same method. The convergent is corresponding to the “approaches” and the divergent is corresponding to the “outcomes” as Figure 4.3 shows.

Logic & Reasoning: It is easy to notice that Piaget directly indicated the children’s logic and reasoning development by naming the third and fourth cognitive development stages, the concrete operational stage (7 to 11) and formal operational stage (11 to adulthood). During the concrete operational stage, concrete events and objects will be applied for solving problems, in which case children are using inductive logic, “going from a specific experience to a general principle” (Cherry, 2018, para. 2). During the formal operational stage, children are capable of understanding the world by using deductive reasoning, “using a general principle to determine the outcome of a specific event” (Cherry, 2018, para. 3). Dumontheil (2014) stated that children during pre-operational stage develop the relational reasoning. “Children under 5 years can solve 0- and 1- relational problems, but fail to solve 2-relational problems” (Dumontheil, 2014, p. 6). She also indicated that the focus of relational reasoning will shift from object similarity to

relational similarity, which will promote the inductive reasoning that dominate the concrete operational stage. So, children's logic and reasoning ability is developing from the simple relational logic and reasoning during the pre-operational stage (2 to 7) to inductive logic and reasoning during the concrete operational stage (7 to 11), then to deductive logic and reasoning in formal operational stage (11 to adulthood). The fast-developing period for logic is the from the starting time of inductive logic to the end of deductive logic, 7 to adulthood.

Age	2 to 7	7 to 11	11 to adulthood
Logic & Reasoning	Simple relational logic	Inductive logic	Deductive logic

Table 4. 11 Development Stages in Logic and Reasoning

Age	0-2	2-7	7-adulthood
Logic & Reasoning			

Table 4. 12 Developing Status in Logic and Reasoning

4.2.1.1.3 Conservation

According to Piaget (1965), conservation refers the logical thinking ability that allows a person to determine that a certain quantity will remain the same despite adjustment of the container, shape, or apparent size. He pointed out that children start to develop this ability during the concrete operational stage from ages 7 to 11. Voyat (1982) presented 150 studies that he and Piaget did to research children's cognitive abilities. Conservation was tested from the aspects of length, shape, volume, number, weight, quantity, etc. As the average statistics, children at the age

of 4 to 8 display absence of conservation; for children at the age of 6 to 10, conservation is a possibility; children at the age of 7 to 11 are capable of conservation. Rubin, Fei and Vandenberg (1983) argued that children are developing the conservation ability at a much earlier age when comparing with Piaget's opinions. They proposed that the children who are enjoying make-believe play are already mastering two conservation abilities, which is decentration, the ability that they can be themselves and the imagined role at the same time, and reversibility, the ability to switch the role back to themselves from the play at any time. Though Piaget justified that children are not able to utilize conservation skills for achieving tasks, the conservation ability starts to emerge from the age of 3, at which age the symbolic play dominates the play type. In summary, conservation starts to develop from 3 but there is no sign that children are able to use this ability on their own from 3 to 8. There is a possibility that children can obtain the ability at the age of 6 to 10. And children are capable of it from 7 to 11.

Age	0-3	3-7	7-10	10+
Conservation				

Table 4. 13 Developing Status in Conservation

4.2.1.1.4 Learning

Attributes: The attributes aspect represents the attributes that the open-ended toy is able to deliver. According to Piaget's theory of assimilation and accommodation, children can absorb new information by updating the existing cognitive structure or reconfiguring to a new structure. The new information includes all kinds of knowledge, for example, language, habits, skills,

mathematics, and etc. For children who are too young to enter the elementary school, play serves a significant role in transforming the new information becoming into their own attributes. Open-ended toys are always delivering knowledge in a concealed way, such as the built-in mathematics properties in block toys playing and color recognizing properties in crayon drawing. Because the knowledge that different toys provided may vary dramatically, when analyzing this section, the exact attributes need to be provided.

Complexity: The complexity aspect in this paragraph is defined as the complexity in one attribute. There are three ways to complicate an attribute, quantity, variety and advanced complexity. The quantity represents the complexity in the number of the existing attribute. The variety represents the complexity in the types of the existing attribute. The advanced complexity represents the advancing attribute compares to the original one. Although it is not possible to identify the emergent age and complexity development age range of every single attribute, it is possible to reason that the development of attribute complexity must accompanied by the age development. Because learning is developing step by step and level by level, one cannot leap to the second step without touching the first step. The Figure 4.2 shows an example of different complexities in number and mathematical attributes. So when the design is exploring the complexity of any attributes, a figure that shows the complexity relationship need to be displayed as in Figure 4.2.

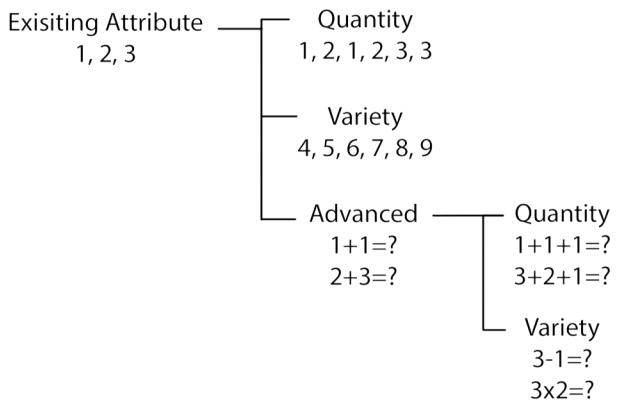

Figure 4. 2 Example of attribute complexity

4.2.1.2 Social Development

4.2.1.2.1 Social Play

Children's social play development is basically following the sequence that Parten's stage of play theory and Howes's social play level theory contain, from unoccupied play to solitary play, to onlooker behaviors, to parallel play, to parallel play with mutual regard, to associative play, to simple social play, to complementary and reciprocal play with mutual awareness, to complementary and reciprocal social play (cooperative play). The corresponding social developments have been summarized in Table 4.14 according to the related research provided earlier in the Chapter 2. (Parten, 1932; Johnson et al., 1987; Jona, 2010; Howes, 1980) The initial development time for social play is during the parallel play and the fast-growing time is from associative play to the end of the pre-operational stage (7 years old), because when children are playing games with rule at the formal operation stage (7 to 11), they are already mastering the cooperative play, last stage of social play.

Age	0 to 3m	3m to 3	Transitional	2.5 to 3.5	Transitional
Play Stage	Unoccupied play	Solitary play	Onlooker behavior	Parallel play	Parallel play with mutual regard
Social Development	Unsocial	Unsocial	Social contacts emerge		Social awareness emerge
Age	3.5 to 4.5	Tansitional		4.5+	
Play Stage	Associative play	Simple social play	Complementary and reciprocal play with mutual awareness	Complementary and reciprocal social play (Cooperative play)	
Social Development	Socializing emerge		Social interaction emerge	Social activity well-developed	

Table 4. 14 Social play stages and social development stages

4.2.1.2.2 Perspective taking

Perspective taking is the ability "to see things from other people's point of view" (Johnson et al, 1987, p. 101). This ability cannot be owned at a young age or all of a sudden, because humans are born to be egocentric, and perspective taking is deeply opposed to this human nature. At two years of age, the child starts to realize the objects exist even though he doesn't see it, and this is also the first step in which he moves from egocentric to objective thinking and perspective taking. Mother's role (mostly) involved in the symbolic play during the age from 2 to 4 also helps the child to think, observe, and deliver another role in his play, which benefits the development of perspective taking. From 4 to 7, the dominated symbolic play changes from dramatic play to social-dramatic play, the dominated social play changes from parallel play and associative play to cooperative play. Both of these two aspects of play require well-developed perspective taking skills to ensure the successfulness of the play. From 7 to adulthood, the dominated play type becomes into game with rules. This is the stage that children get in touch with strictly defined rules when playing and it's also the foundation of social norms. Children finally are able to master the perspective taking.

4.2.1.2.3 Compiled Developing Status in Social Aspect

Ability	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7+
Social Play								
Perspective Taking								

Table 4. 15 Developing Status in Social Aspect

4.2.1.3 Motor Development

4.2.1.3.1 Stability, Locomotor and Manipulation

According to Gallahue's (1976) theory of motor development, stability ability, locomotor ability and manipulative ability represents the children's motor development status. The movement development stages are reflexive stage, rudimentary stage, fundamental stage, and specialized stage. Because the specialized movement abilities are an outgrowth of the fundamental movement abilities that become tools applied for the use of daily life, from the standpoint of development, all the abilities are well-developed. So the ability development in fundamental movement stage will be emphasized. Gallahue and Ozmun (2002) used some selected abilities to represent the stability, locomotor and manipulative ability. Stability ability contains dynamic balance (the ability that maintaining one's equilibrium as the center of gravity shifts) and static balance (the ability that maintaining one's equilibrium while the center of gravity remains stationary). The locomotor ability includes walking and running, jumping and hopping, and galloping and skipping. The manipulative ability holds grasping, throwing and catching, striking and kicking.

Age		1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7
Stability Ability	**Dynamic Balance**			Walks 1-inch straight line; Walks on 4-inch beam	Walks 1-inch circular line; Walks on 2- or 3-inch beam		
	Static Balance	Stands alone				Balances on one foot 3-5 seconds	
Locomotor Ability	**Walking & Running**	Mature walk	First true run		Efficient and refined run	Mature run	
	Jumping & Hopping		Jump down from object	Hops 3 times on preferred foot	Hops 4 to 6 times on same foot	Jump for distance and height; Hops 8 to 10 times on same foot	Mature jump; Mature hop
	Galloping & Skipping				Inefficient gallop; One-footed skip	Skillful skipping	Skillful Galloping
Manipulative Ability	**Grasping**	Controlled pincer grasp and release	Grasp crayon with thumb and fingers			Grasp pencil with three fingers	
	Throwing & Catching		Throw with forearm only; Respond with delayed arm movement (catch)	Throw with forearm and body rotation; Catch with body		Catch with hands	Mature throwing; Mature catching
	Striking		Swing in a vertical plane		Swing in a horizontal plane	Using body weight	Mature striking
	Kicking	Only push, no kick	Kick with straight leg, little body movement	Flex lower leg backward	Greater backward and forward swing	Mature kicking	

Table 4. 16 Development Stages in Stability, Locomotor and Manipulative Ability

4.2.1.3.2 Visual Perception

According to Gallahue and Ozmun (2002), children's visual apparatus is mature when reaching the age of 2, while their abilities of visual perception are still incomplete. The visual perception can be summarized into several major aspects, visual acuity (the ability to distinguish details), figure-ground perception (the ability to separate one object from its surrounding visually), and visual-motor coordination (the ability to integrate using of eyes and hands). Gallahue and Ozmun (2002) provided the development status of these three visual perception abilities (see Table 4.17).

Age	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Visual Acuity			Rapid improvement		Plateau		Rapid improvement	Mature (static) Plateau (dynamic)	Mature (dynamic)
Figure-ground Perception	Slow improvement	Rapid improvement			Slight spurt	Mature			
Visual-motor Coordination	Rapid improvement				Slow slight improvement			Mature	

Table 4. 17 Developing Status in Visual Perception

4.2.1.3.3 Compiled Developing Status in Motor Aspect

Ability		0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12+
Stability	Dynamic Balance													
	Static Balance													
Locomotor	Walking & Running													
	Jumping & Hopping													
	Galloping & Skipping													
Manipulation	Grasping													
	Throwing & Catching													
	Striking													
	Kicking													
Visual Perception	Visual Acuity													
	Figure-ground Perception													
	Visual-motor Coordination													

Table 4. 18 Developing Status in Motor Aspect

4.2.1.4 Compiled Ability Development Table

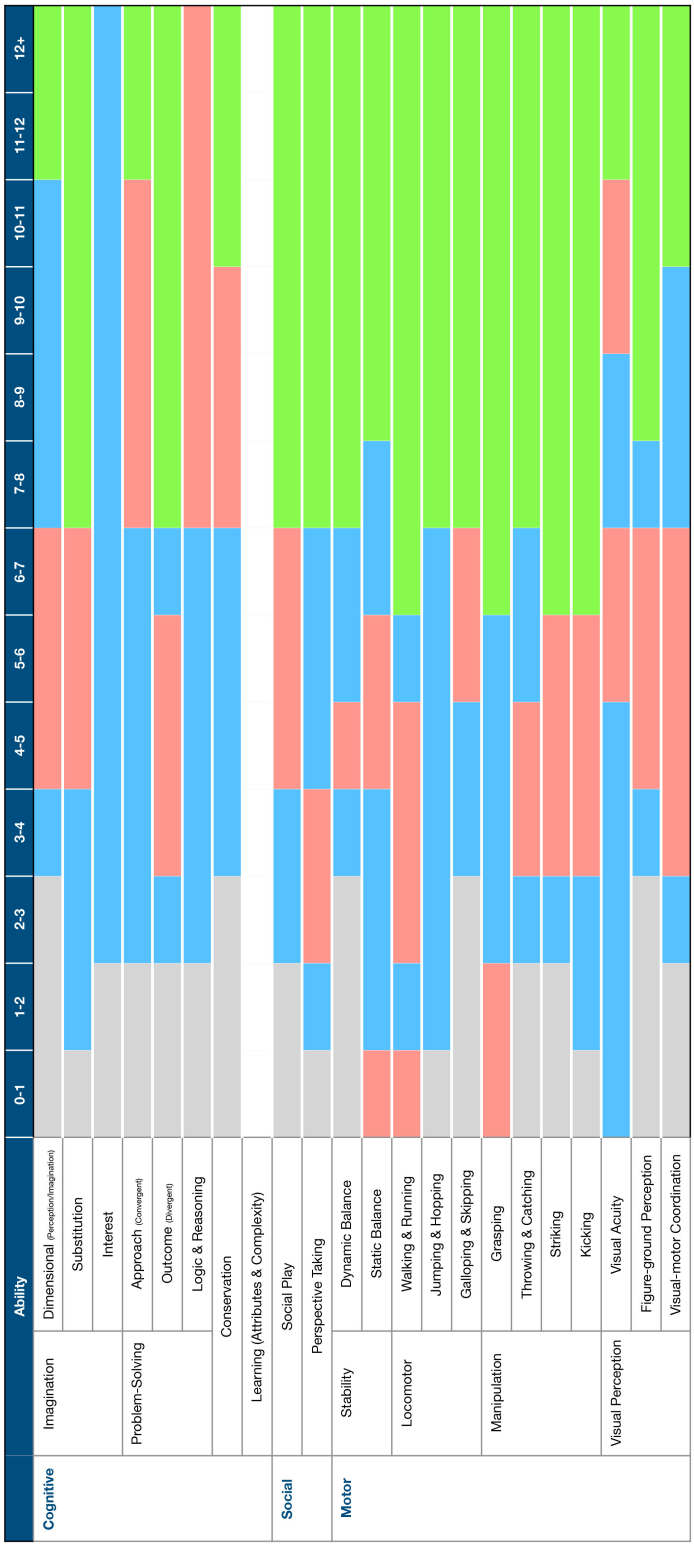

Table 4. 19 Compiled Ability Development Table

4.2.2 The Process of Criteria Study

Firstly, the designer needs to crop the pre-defined ability development table with the selected age range. Then, designer is able to study that table and get to know the importance of ability developing in different ages.

Secondly, the designer needs to use the list in the ability table to study the ability distribution in the existing products. When selecting the products, designers need to select as wide range as possible in order to include all the possibilities. The selected products need to be in the same age range. A check mark will be made if one ability is contained. After all the selected existing products are checked, the designer will get a sum number of each ability.

Lastly, designer uses the cropped ability table and the ability distribution study in existing products as references to select the ability that the concept will be focusing on. The selected abilities are also going to be used to generate the scores for judging the concepts during the evaluation step. The table can point out the importance of each ability in the selected age range. The distribution study can deliver the message of the most popular and unpopular abilities in the market. Then, the designer needs to analyze the reason behind the unpopular ability, whether it's unrelated to the toy type or simply ignored by the market which could be a great potential to discover.

One special consideration is the learning abilities in cognitive development. Because there are infinite attributes that children can learn, it is not possible to list every single one in the pre-defined ability table. When studying the existing products, attributes will be abstracted. Then

designer needs to study the attributes' development process in order to have them added into the ability table.

An example to clarify the approach above: The decided age range is from X to X+4. The cropped ability table shows the development of ability A, B, C, D, E, from X to X+4 years of age (see Table 4.20). From the Table 4.21, the ability distribution in the existing product is summarized. Ability A, B and D have the highest distribution. Ability C and E are the most unpopular ability in the market. Through more research, designer found that the ability C is an unrelative ability with the selected toy type and ability E is a potential ability that the market is not discovering. The designer finally selected the ability A, B, D, and E.

	X to X+1	X+1 to X+2	X+2 to X+3	X+3 to X+4
Ability A				
Ability B				
Ability C				
Ability D				
Ability E				

Table 4. 20 Example of Cropped Ability Development Table from X to X+4

	Product 1	Product 2	Product 3	Product 4	Product 5	Product 6	Product 7	Product 8	SUM	Selection	Reason
Ability A	✓	✓		✓	✓	✓		✓	6	✓	Popular Ability
Ability B	✓	✓	✓	✓	✓	✓	✓	✓	8	✓	Popular Ability
Ability C					✓				1		Irrelative Ability
Ability D	✓	✓	✓	✓				✓	5	✓	Popular Ability
Ability E			✓				✓		2	✓	Potential Ability

Table 4. 21 Example of Existing Product Criteria Study

4.3 Decompositions

Decomposition is the step that uses developed criteria to divide the entire age range into sub-stages. The sub-stages represent the stages for each concept in the later step. After the decomposition, all the abilities in certain stage need to remain still, while, different abilities vary greatly in their stage-changing ages, so eventually, some abilities will need to compromise. The ability table can provide the designer the least compromised ability number for dividing the stage. But the designer can still make a different choice subjectively based on the significance of each ability.

Still using the previous example to demonstrate the decomposition step, if the designer input three stages for decomposing, it is easy for the designer to make the first decomposing position (X+3) because all the abilities have a stage-change at the age of X+3. But when considering about the second cut, the designer needs to compromise the Ability D (Figure 4.3) or Ability A and E (Figure 4.4).

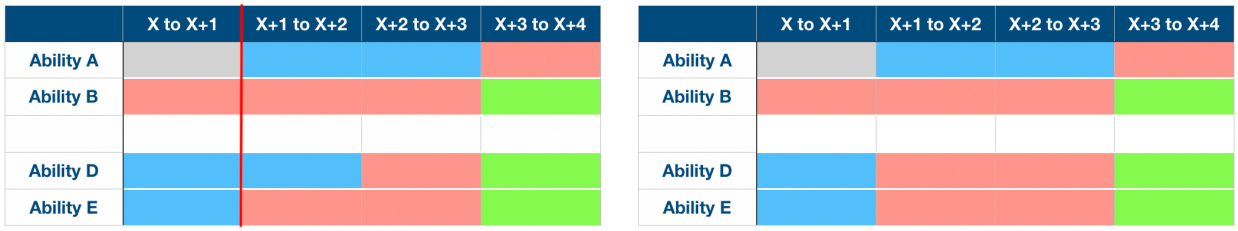

Figure 4. 3 Example of Decomposition Option One

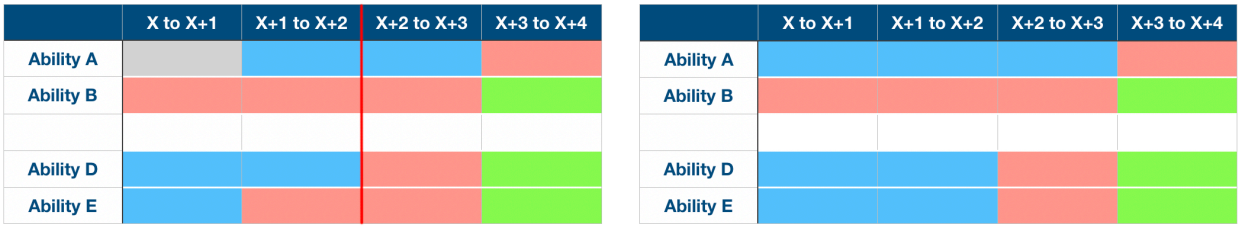

Figure 4. 4 Example of Decomposition Option Two

4.4 Concept Generating

This step is generating concepts based on the refined ability development table. Each concept must involve all the decomposed stages. The concepts are generated surrounding how to meet the needs of abilities' development. Concepts are varied based on the different abilities that met in different stages.

4.4.1 Modularity Concerns

Growable modular design is basic principle. When developing a concept, designers need to think frequently about how the product is able to grow and become the product for the use of next stages. Because the concepts are all "ability-based", using the abilities' growth to define the relationship between each product and module will make the design process easier. Another big modularity concern is the interfaces. Modular product system is a great benefit on the standardized interfaces. The interfaces can be either physical or virtual. As the example shows in Figure 4.5, the toy on the left has the physical connection (interfaces) and the toy one the right has the virtual interfaces, which means different play sets can be played together for one play.

Figure 4. 5 Examples of Physical and Virtual Interfaces

4.4.2 Cross-stage Modularity Approaches

Two modularity approaches can be used to define the concept's relationship across stages (as Figure 4.6). First, Product 1 in Stage 1 is fully functional. When the product is developed into Stage 2, Module 2 can be plugged into the Product 1 and become Product 2. Second, Product 1 in Stage 1 is fully functioned. When the product is developing into Stage 2, Product 2 serves as a fully functioned product, and Product 1 or some parts of Product 1 can serve as Module 1 for plugging into the Product 2 in order to promote it into Product 2.1. Both of these two approaches meet the requirement of growable products and designers need to decide which one suits better.

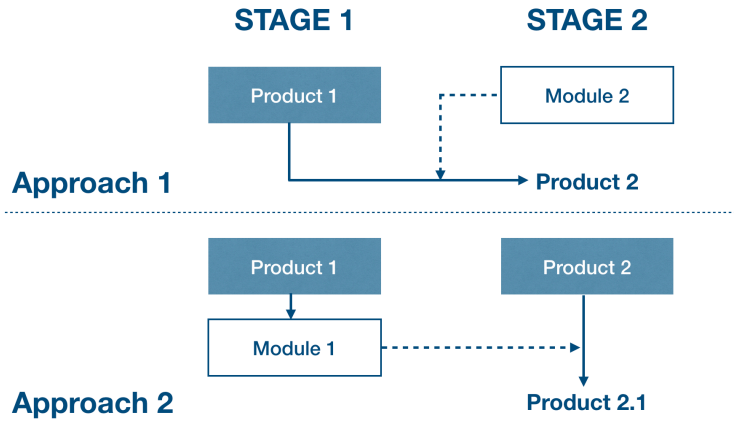

Figure 4. 6 Illustration of Two Cross-stage Modularity Approaches

4.4.3 Same-stage Modularity Approach

Because all the modules have self-contained functions, by plugging in a new module, the product can successfully upgrade into a newer version. But one thing that the designer needs to pay attention to is whether the ability (function) that the module contains can be used for this stage. If not, this module actually belongs to the cross-stage modularity approach 1 in Figure 4.6.

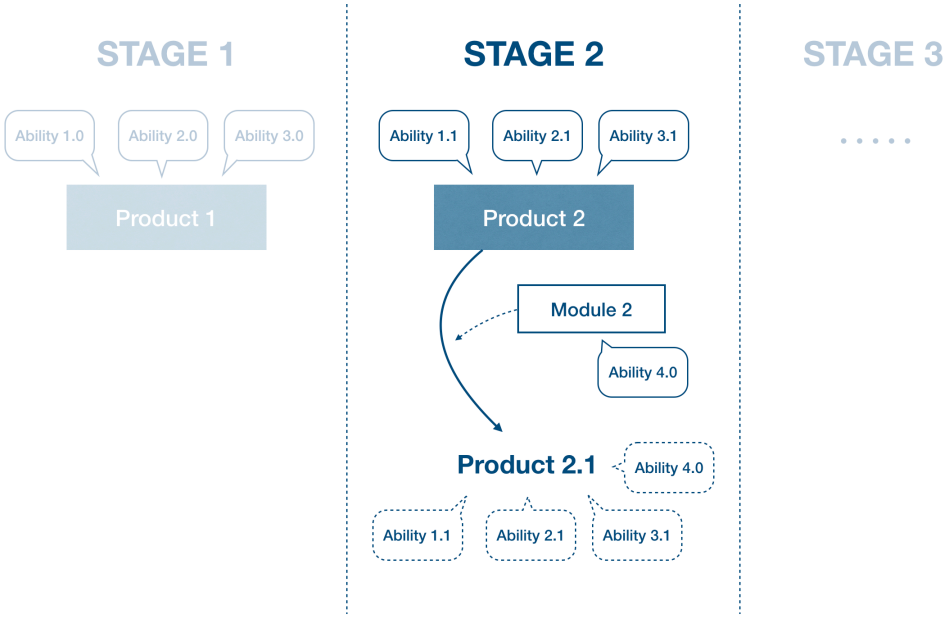

Figure 4. 7 Illustration of Secondary Decomposition

4.5 Evaluation

This step evaluates the concepts into scores by filling the ability grading chart and calculating the scores for each stage. The evaluation gives designer a more rational way to judge different concepts and their performance in different stages.

4.5.1 Ability Grading

During the ability grading, a grading table (as in Table 4.22) needs to be created first with the options for grading all the abilities in all the stages for all the design concepts. The grade point is between 0 to 10 based on each concept's performance. Grading as 0 represents no ability promotion. Grading from 1 to 3 represents poor performance of ability promotion, 4 to 6 represents medium level performance, 7 to 9 represents good performance. And grading as 10 represents the best performance of ability promotion. Although grading is a subjective scoring method, when grading each ability, having all the concepts graded together with comparison will make the grading more objective. For example, when grading the ability B in stage 1, all of the three designs will be considered and graded together as the score of 8, 6, and 10 (Table 4.23). When grading for each stage, designer needs to consider the functions of the new product or module individually rather than the whole product system. Because the final score that is generated in each stage embodies the performance of each product or module in the digitalized way, designer can clearly realize the weakest and strongest stage in this product system which will benefit the refining process in the future.

	STAGE 1			STAGE 2			STAGE 3		
	Design 1	Design 2	Design 3	Design 1	Design 2	Design 3	Design 1	Design 2	Design 3
Ability A									
Ability B									
Ability D									
Ability E									

Table 4. 22 Example of Ability Grading Table

	STAGE 1			STAGE 2			STAGE 3		
	Design 1	Design 2	Design 3	Design 1	Design 2	Design 3	Design 1	Design 2	Design 3
Ability A				10	7	8	9	8	6
Ability B	8	6	10	4	6	5	6	6	8
Ability D	6	9	4	8	5	2	10	7	5
Ability E	7	5	6	8	9	10	6	7	9

Table 4. 23 Example of Finished Ability Grading Table

4.5.2 Evaluating Calculation

Firstly, the designer must convert (calculate) the score corresponding to the actual value scale. Because the ability in each stage has its own value that was already defined earlier (grey = 0, blue = 1, red = 2, green = 3) (see Table 4.24), the grades (0 to 10) need to be transferred into the correct value scale. The equation is: Score Design X (Ability Y in Stage Z) = (Graded Score * Value (Ability Y in Stage Z)) / 10.

For example, when converting the graded number of Design one in Ability B at Stage 3, the calculation will be: Score Design 1 (Ability B in Stage 3) = (Graded Score * Value (Ability B in Stage 3)) / 10 = (6 * 3) / 10 = 1.8 (Table 4.25).

	STAGE 1				STAGE 2				STAGE 3			
	X to X+1	Design 1	Design 2	Design 3	X+1 to X+3	Design 1	Design 2	Design 3	X+3 to X+4	Design 1	Design 2	Design 3
Ability A	0				1	10	7	8	2	9	8	6
Ability B	2	8	6	10	2	4	6	5	3	6	6	8
Ability D	1	6	9	4	2	8	5	2	3	10	7	5
Ability E	1	7	5	6	2	8	9	10	3	6	7	9

Table 4. 24 Example of Graded Table with Value

Secondly, the designer must calculate each design's score as a percentage in each stage. The first step is calculating each stage's sum score and each design's sum score in each stage. The second step is using the first score divided by the second score and getting the final percentage score.

For example, if calculating the score of Design 3 in Stage 2, sum score in stage 2 = 1 + 2 + 2 + 2 = 7, sum score of Design 3 in Stage 2 = 0.8 + 1.0 + 0.4 + 2.0 = 4.2, and final score = 4.2 / 7 = 60% (see Table 4.25).

	STAGE 1				STAGE 2				STAGE 3			
	X to X+1	Design 1	Design 2	Design 3	X+1 to X+3	Design 1	Design 2	Design 3	X+3 to X+4	Design 1	Design 2	Design 3
Ability A	0				1	1.0	0.7	0.8	2	1.8	1.6	1.2
Ability B	2	1.6	1.2	2	2	0.8	1.2	1.0	3	1.8	1.8	2.4
Ability D	1	0.6	0.9	0.4	2	1.6	1.0	0.4	3	3.0	2.1	1.5
Ability E	1	0.7	0.5	0.6	2	1.6	1.8	2.0	3	1.8	2.1	2.7
SUM	4	2.9	2.6	3	7	5	4.7	4.2	11	8.4	7.6	7.8
Score		72.5%	65.0%	75.0%		71.4%	67.1%	60.0%		76.4%	69.1%	70.1%

Table 4. 25 Example of Score Converting Calculation

Lastly, the score for each design will be made by calculating the average score (See Table 4.26).

	Design 1	Design 2	Design 3
STAGE 1	72.5%	65.0%	75.0%
STAGE 2	71.4%	67.1	60.0%
STAGE 3	76.4%	69.1%	70.1%
Avg.	**73.4%**	**67.1%**	**68.4%**

Table 4. 26 Example of Average Score Calculation

After the evaluation, the concept with the highest score represents the most appropriate concept that meets the criteria in all three stages. Because scores in each stage are provided individually, designer has the choice to go back to the last step for refining the concept product or module independently.

4.6 Final Delivery

For final delivery, it is necessary to develop a systematic concept instruction for clear explanation of the whole concept. It should contain toy type, age range, concept tree (products and modules in each stage and the relationship between them), ability developing chart (the children development abilities that the product system meets), and ability distribution chart (how the abilities in each stage meet by products and modules) (Figure 4.8).

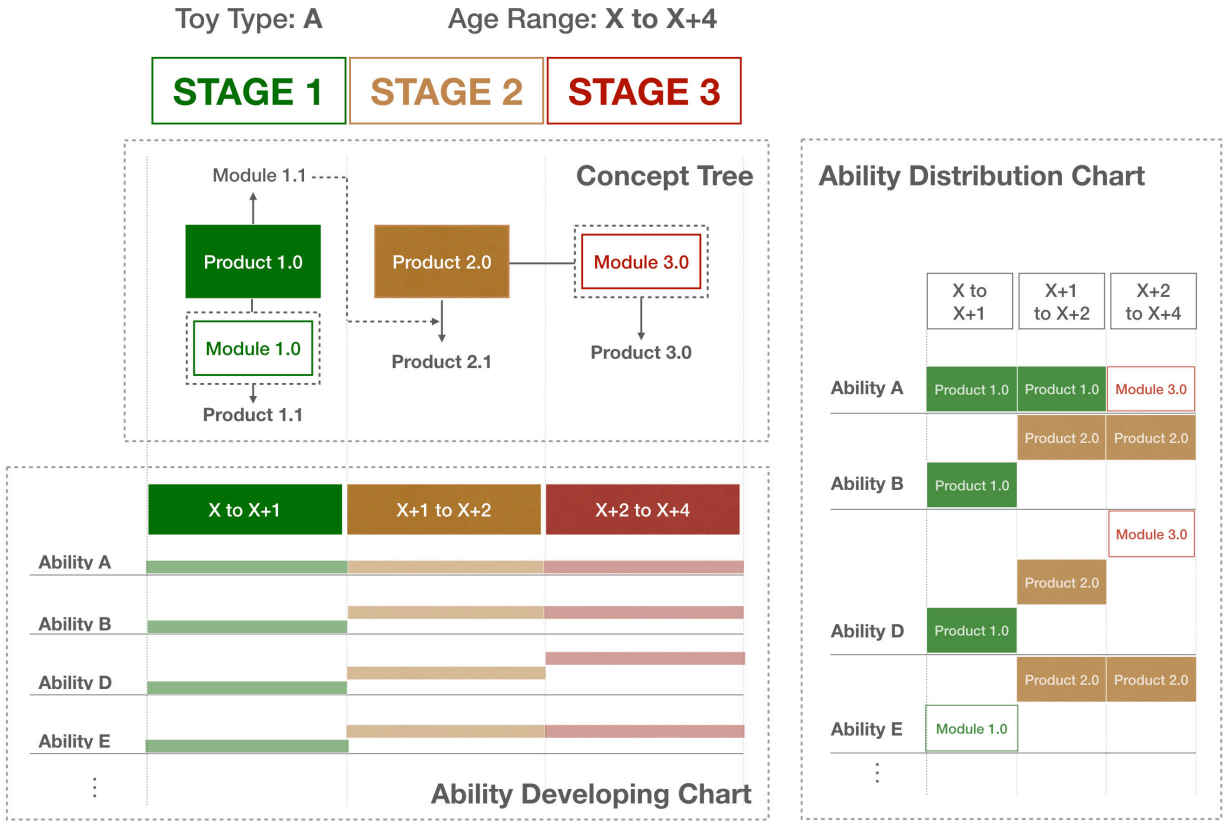

Figure 4. 8 Example of Final Delivery

4.7 Further Development

The last step is further development, an optional step that gives the designers the opportunity to make updates and upgrades for the existing product system. It can either introduce a new version of product or supply the older version product with newly designed modules. After this step, the designer still needs to go back to the evaluation step to re-evaluate the concepts and update the final delivery.

Chapter 5 Design Application

In this chapter, the approach described in the last chapter will be demonstrated with a design application. The sequence will be the same as the flow chart in Figure 4.1.

5.1 Identify

The selected toy type is block toys and the age range is 3 to 8. According to Maria and R.L. Edgeworth's Practical Education, the block toys are described as the buildable toy that teaches children about gravity, physics, and the relationship between part and whole (Rybczynski, 1993). One block set contains several individual blocks. The toy can be used to explore children's imagination and manipulation skills. Block toy do not have any interlocking system, which is a great difference when comparing with construction toys such as LEGO.

5.2 Criteria Study

5.2.1 Cropped Ability Development Table Study

The first step in criteria study is to crop the ability table to the selected age range (Table 5.1) and study the ability developing.

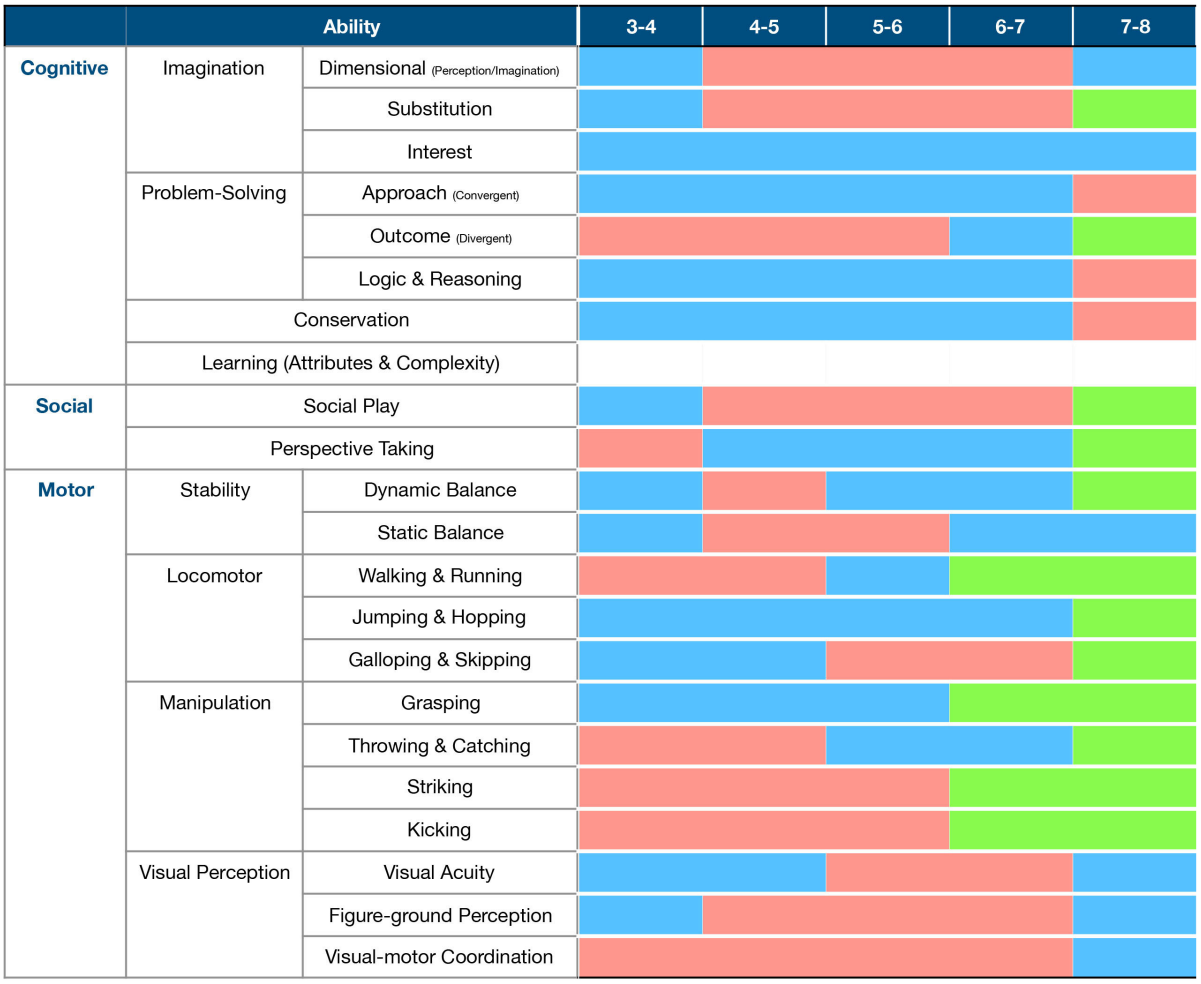

Table 5. 1 Cropped Ability Development Table

5.2.2 Ability Distribution Study

Ten existing products (see Figure 5.1) have been selected for the criteria study. The study includes different abilities in cognitive, social and motor development. In the learning section of cognitive development, several attributes have been discovered from the studied products, which are gravity, mathematics, shape, color pattern, and alphabets. All the abilites are checked with a sum number at the end (see Table 5.2).

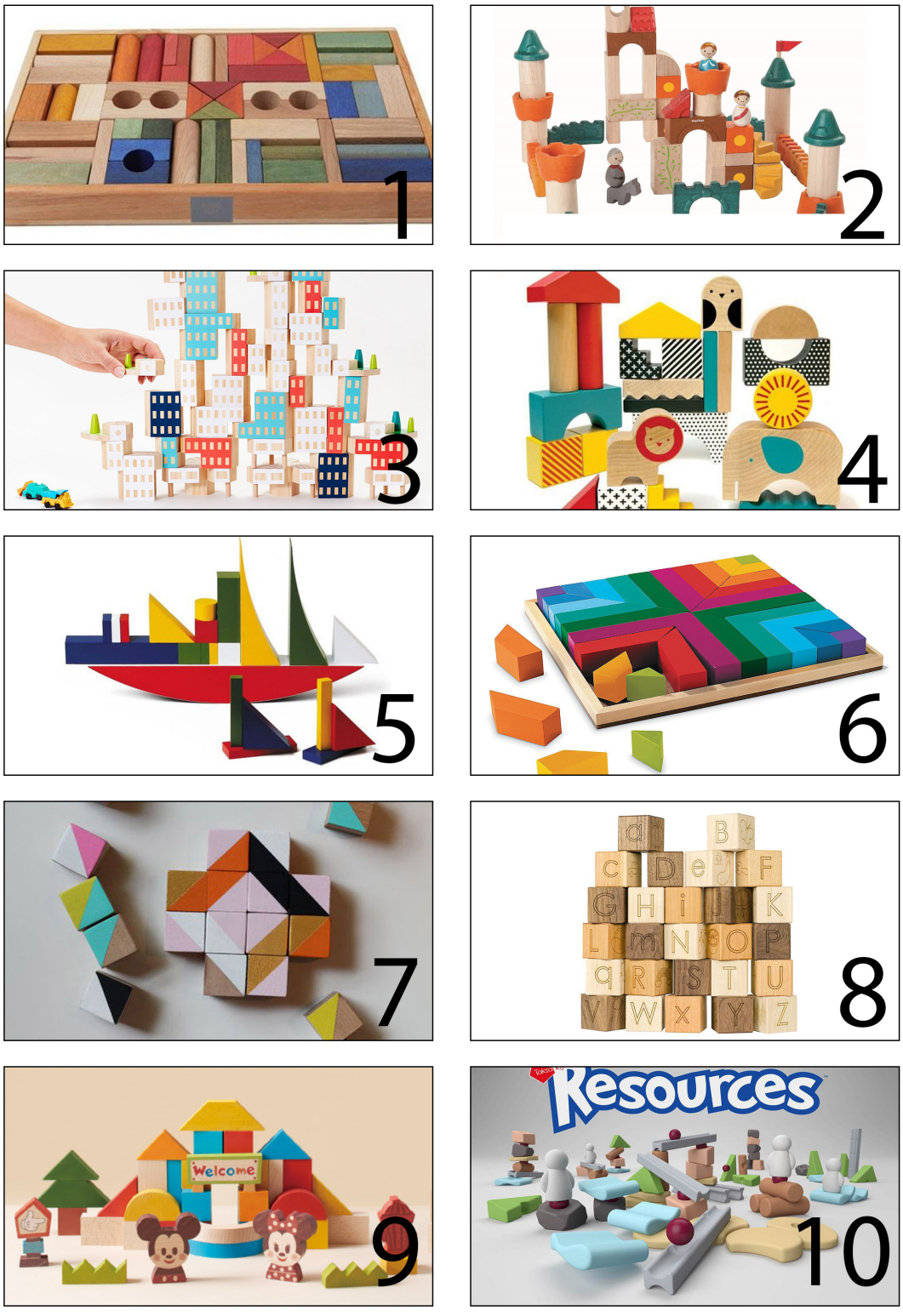

Figure 5. 1 Selected Existing Products

			1	2	3	4	5	6	7	8	9	10	SUM
Cognitive	Dimensional (Perception/Imagination)		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
	Substitution		✓	✓	✓	✓	✓				✓	✓	7
	Approach (Convergent)		✓		✓		✓	✓	✓				5
	Outcome (Divergent)		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
	Interest			✓		✓					✓	✓	4
	Logic & Reasoning		✓		✓		✓	✓	✓			✓	7
	Conservation		✓					✓	✓	✓			4
	Attributes & Compexity	Gravity	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
		Angle	✓				✓	✓	✓		✓		5
		Proportion	✓		✓	✓	✓	✓			✓		6
		Shape	✓			✓	✓	✓			✓	✓	6
		Stability	✓		✓	✓	✓			✓	✓	✓	7
		Length	✓			✓	✓	✓					4
		Color Pattern						✓	✓	✓			3
		Alphabets								✓			1
Social	Social Play		✓	✓		✓					✓	✓	5
	Perspective Taking												
Motor	Dynamic Balance												
	Static Balance												
	Walking & Running												
	Jumping & Hopping												
	Galloping & Skipping												
	Grasping		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
	Throwing & Catching												
	Striking												
	Kicking												
	Visual Acuity			✓	✓	✓		✓	✓				5
	Figure-ground Perception							✓	✓				2
	Visual-motor Coordination		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10

Table 5. 2 Existing Product Ability Distribution Chart

5.2.3 Ability Analyzation and Selection

The last step is analyzing each ability for selection.

Dimensional (perception/imagination): All the block toys are enabe children to have the imagination expressed either in a two-dimensional (toy 6 and toy 7) or three-dimensional way. The age from 4 to 7, the fastest developing time is also involved in the selected age range. This ability is selected.

Substitution: Substitution is one of the most significant abilities in children's symbolic play, especially at the age of 2 to 7. This ability is selected.

Approach (Convergent): The ability of approach is rapidly developing from 7 to 11 and mildly developing from 2 to 7. This ability is selected.

Outcome (Divergent): The ability of outcome grows dramatically in the pre-operational stage (2 to 7). The versatility of block toys can enable full discovery of this ability. This ability is selected.

Interest: Block toys have a poor ability to catch children's interests in theme and role, because seldom do block toys provide the figure and theme play. This ability is not selected.

Logic & Reasoning: Children at the age of 2 to 7 are only able to use simple relational logic. But the block toy provides children a good opportunity to develop their logic ability through the individual properties such as shape, length, ratio. This ability is selected.

Conservation: Children at 3 to 8 are developing conservation ability at a relatively low speed. Block toy can train children's conservation ability. This ability is selected.

Gravity (learning attribute): Gravity is the attribute that children will learn as long as they touch block toys. All the buildings that are built with the block toy utilize this ability. There is no complexity for children to learn the gravity, so the developing status will remain the same from 3 to 8. This ability is selected.

Mathematic (learning attribute): Mathematic learning in the block toy is a benefit from the built-in property of this type of toy. By having this property, the block toy has the ability to be explored in various ways. The mathematic ability can definitely become more complex, especially after children enter the elementary school (6+). This ability is selected.

Shape (learning attribute): Shapes learning in block toys is more advanced than the earlier age shape sorting activity. Children can always explore the different combinations of shapes. Research stated that block toys always have simple geometric form at the age of 3. But it will develop into more specialized forms from 4 years old (Phillips, 2018). So the age from 3 to 4 is the rapid developing stage. This ability is selected.

Color Pattern (learning attribute): Color pattern was owned by two 2D block toys in the study. Because it's the ability that cannot be developed during the block-building play, this ability is not selected.

Alphabets (learning attribute): Only one in ten toys owns this ability. Alphabets learning is towards more a closed-ended learning. In this case, the closed-ended learning toy can serve a better job. So this ability is not selected.

Social Play: There is no block toy (in this study) that has been found that promotes the social play. But there is no reason to reject the development of social play in block play. Since this ability may have some potential, it is selected.

Grasping: Grasping is the main behaviors when playing with block toys. This ability is selected.

Visual Acuity: Visual acuity is the ability to distinguish the details. There is little possibility for block toys to develop this ability. This ability is not selected.

Visual-motor Coordination: This is the ability that integrates the use of eyes and hands. It's a fundamental ability that children needed in block play because children need to pick up and drop the toys frequently. This ability is selected.

	Ability		3-4	4-5	5-6	6-7	7-8
Cognitive	Imagination	Dimensional (Perception/Imagination)					
		Substitution					
	Problem-Solving	Approach (Convergent)					
		Outcome (Divergent)					
		Logic & Reasoning					
	Conservation						
	Learning (Attributes & Complexity)	Gravity					
		Mathematic					
		Shape					
Social	Social Play						
	Perspective Taking						
Motor	Manipulation	Grasping					
	Visual Perception	Visual-motor Coordination					

Table 5. 3 Ability Developing Table with Selected Abilities

5.3 Decomposition

The age range is going to be divided into three stages. The cuts are going to be at the position of 4 years old (5 nodes) and 7 years old (10 nodes). Three abilities' development were compromised.

	Ability		3-4	4-5	5-6	6-7	7-8
Cognitive	Imagination	Dimensional (Perception/Imagination)					
		Substitution					
	Problem-Solving	Approach (Convergent)					
		Outcome (Divergent)					
		Logic & Reasoning					
	Conservation						
	Learning (Attributes & Complexity)	Gravity					
		Mathematic					
		Shape					
Social	Social Play						
	Perspective Taking						
Motor	Manipulation	Grasping					
	Visual Perception	Visual-motor Coordination					

Table 5. 4 Decomposed Ability Table

5.4 Concept Generating

5.4.1 Development of the First Stage

5.4.1.1 Concept One

The first block toy concept is inspired by the modularity property of the equilateral triangle. One big equilateral triangle can consist of 9 small ones. With some small triangles cut out, the shape has more and more possibilities (see Figure 5.2). As shape with 8 triangles has two arrangement possibilities, 7 has four possibilities, 6 has five possibilities, 5 has four possibilities,

and 4 has three possibilities. Because all the knocked-out pieces are the same triangle shape with different amounts and position, when combining pieces together, there is a great chance that pieces can fit seamlessly.

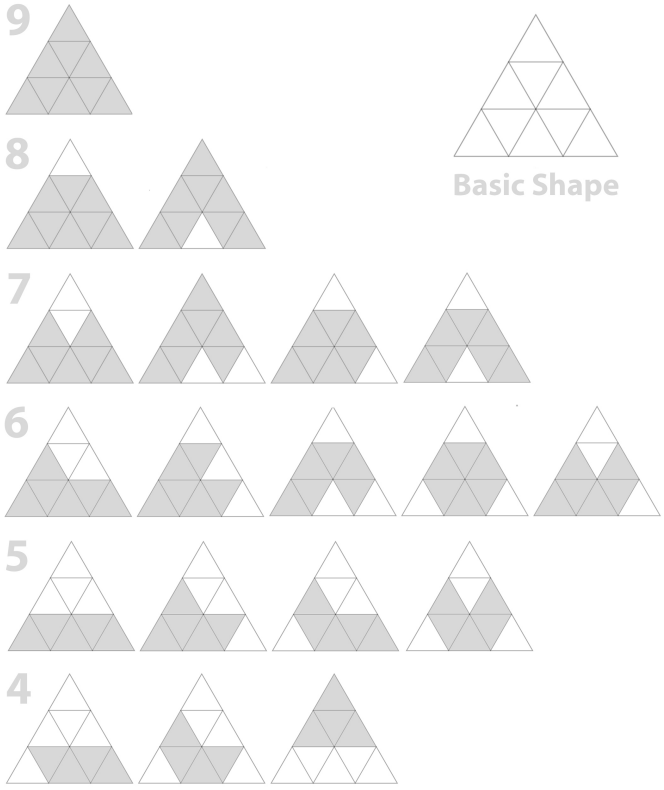

Figure 5. 2 Illustration of the Shape Possibilities of Concept 1

According to the dimensional perception and imagination of the criteria table, children are developing from 2D imagination to 3D. In this concept, the dimensional is transforming from 2D to 2.5D then to 3D. In the first stage, the toy provides children the chance to have their imagination expressed by 2-dimensional pattern blocks. And during the second stage, children can stack the blocks up and play in 2-and-half-dimensional. For the last stage, modules will be added to encourage the play in a more 3-dimentional way.

When selecting the shape for each stage, the interior angle of the shape matters a lot. Except for the straight angle (180º), there are four types of interior angle in this triangle system, which are 60º, 120º, 240º and 300º. The shapes with the interior angle of 300º are removed from the shape of stage one. For one point, blocks in the first stage should have simpler shapes compared to the blocks at the second and the third stage. And having the interior angle of 300º add lots of complexity and possibilities during the play, so obviously it should be appeared at a later stage. From the other point, 300º interior angle benefits a lot when having the stacking play, which is not intended to be owned by the toy at the very first stage (2-dimensional play). The shapes for the first stage are highlighted by red outlines (see Figure 5.4).

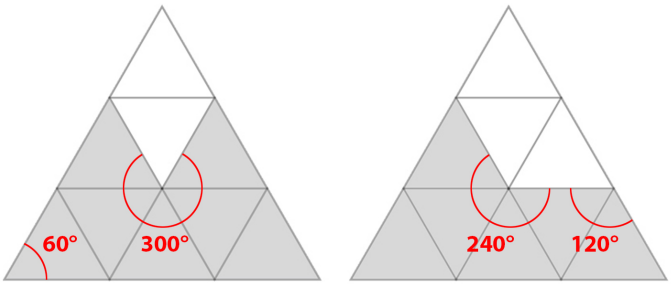

Figure 5. 3 Demonstration of the Four Interior Angles

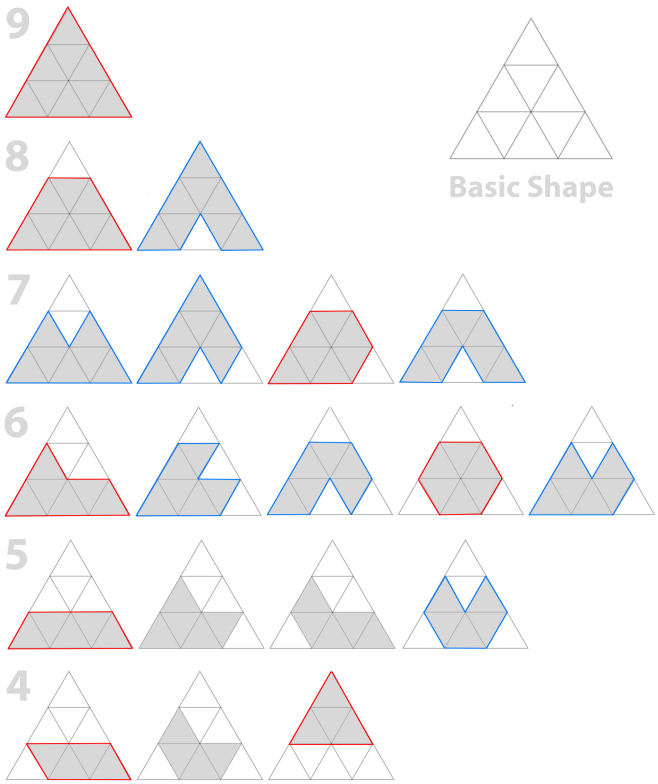

Figure 5. 4 Demonstration of the Shape choosing

Figure 5. 5 Demonstration of the Play Outcomes of Concept One in Stage One

5.4.1.2 Concept Two

Concept two is focusing on the building and architecture block play. The blocks in the first stage only contain the basic shapes such as equicrural triangle, single arch, cubes. All the shapes are created by the help of the grid system (see Figure 5.6). Different to the first concept, the first stage of play focuses on the 2-and-half-dimensional play and simple 3-dimensional play.

All the blocks share the same thickness, since the thickness has the same length as the smallest grid, so there are a lot of playing possibilities that child can explore. And these limited simple shapes can encourage more exploring actions instead of the observing-and-abandoning that Phlipot (2014) suggested in the research.

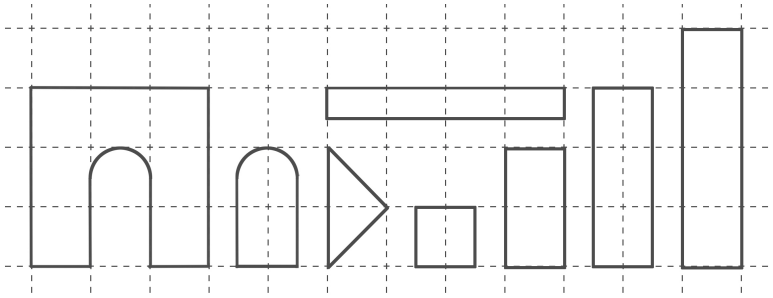

Figure 5. 6 Demonstration of Block Shapes in First Stage for Concept Two

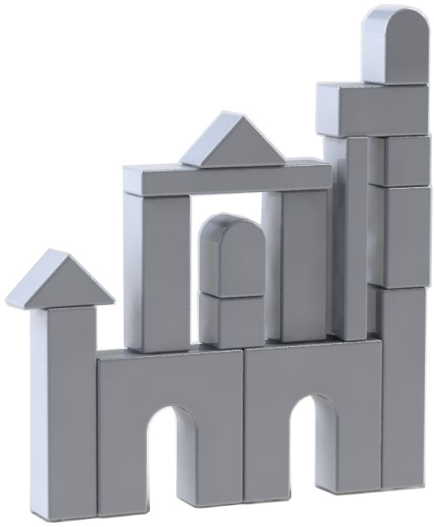

Figure 5. 7 Demonstration of Play Outcomes in First Stage for Concept Two

5.4.2 Development of the Second Stage

5.4.2.1 Concept One

The second step of concept one is selecting the shapes for the second stage. Obviously, shapes in the first stage should be included, because when playing with the toy at the second stage, the original shapes at the first stage are already absorbed into children's cognitive system. Learning new shapes by finding the relationship between them with the well-known shapes will accelerate the learning speed and promote the better playing experience.

The new added shapes are highlighted with blue outlines in Figure 5.4. Compared to the shapes at the first stage, the variety of combination grows dramatically. This is greatly benefitting from the 300º interior angle because among all interior angles, 60º occupied the largest amount. In the eight shapes of first stage, there are 16 out of 34 angles are 60º. And the 300º interior angle can fit seamlessly with 60º interior angle, which critically increases the

varieties of combination. Figure 5.8 shows the varieties created by two selected shapes in the second stage.

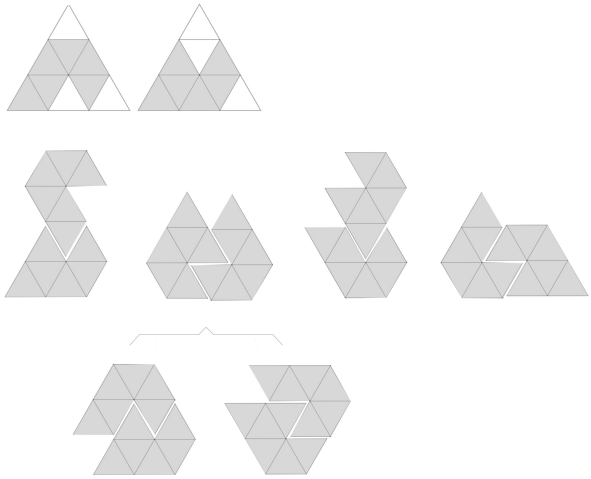

Figure 5. 8 Demonstration of Combination Varieties

5.4.2.2 Concept Two

For the second stage of concept two, more varieties of block were added into the play, so the building play is changing into a more complex play. The one-arch basic shape in stage one develops into three types of new arch blocks, which are straight double-arch, double-arch with right-angle corner, and round top one-arch. With more negative arch-cut shapes brought into the play, it is necessary to involve more positive shapes for fitting the negative cuts. So round column and half-round column are introduced into the play.

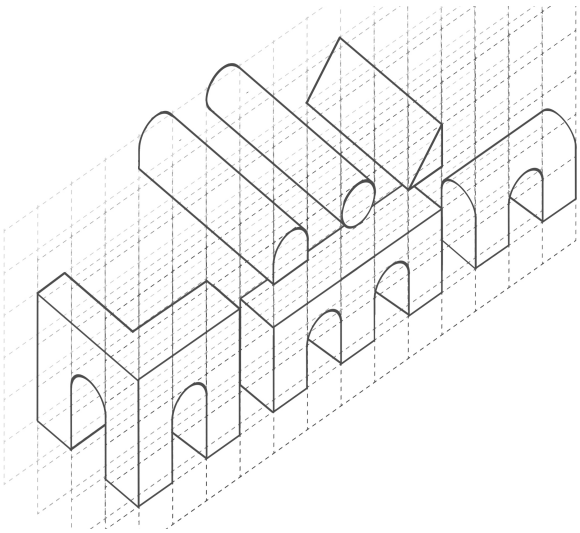

Figure 5. 9 Demonstration of Block Types in Second Stage for Concept Two

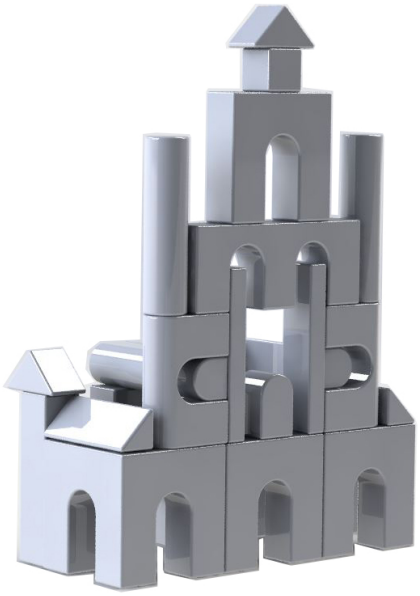

Figure 5. 10 Demonstration of Play Outcomes in Second Stage for Concept Two

5.4.3 Development of the Third Stage

5.4.3.1 Concept One

From stage one to stage two, the block play changes from the patterning play on the surface to building and stacking play on the table. The product/module in the third stage will lead

children's building play to a more 3-dimensional outcome. Two approaches were used to create the blocks in stage three, which are extending and twisting. Extending is aiming at extending the building dimension from only one surface to the front one and the back one. Twisting is used to change the building direction 90º, which will make the building more 3-dimentional (see Figure 5.11). Finally, eight blocks were selected for stage three (see Figure 5.12).

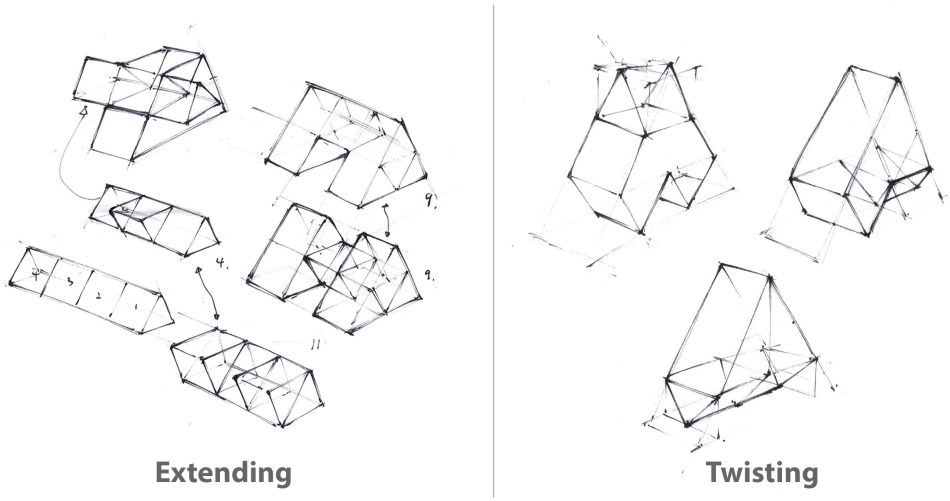

Figure 5. 11 Two Approaches of the Stage Three Block Toys for Concept One

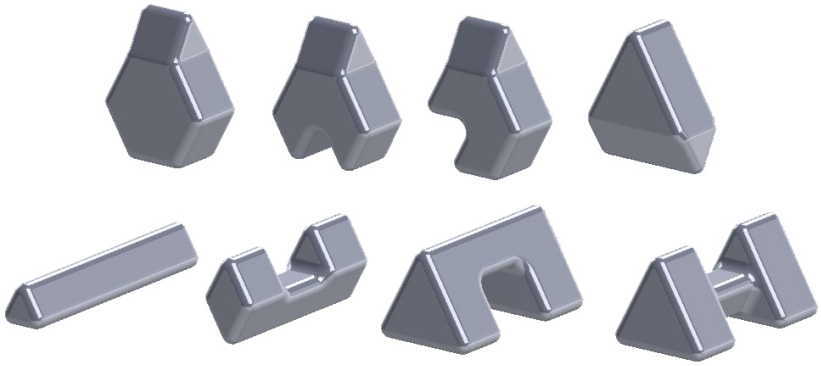

Figure 5. 12 Demonstration of Selected Blocks in the Third Stage for Concept One

5.4.3.2 Concept Two

At the last stage of concept two, characters, cars and a car track were involved in the play. Rather than enhancing the constructive play, blocks in this stage focuses more on story-telling and story line developing which benefits more social play. Although more detailed shapes are blended into the toy system compared to the previous stages, the design are still based on the original grid system (see Figure 5.13).

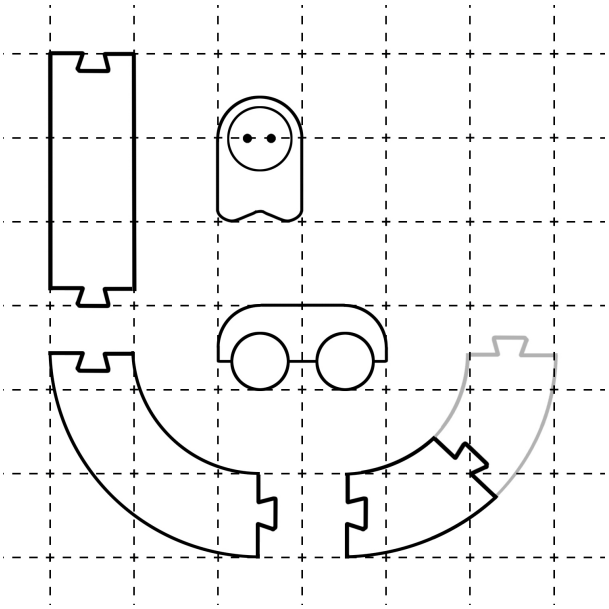

Figure 5. 13 Demonstration of Block Types in Second Stage for Concept Two

Figure 5. 14 Demonstration of Play Outcomes in Third Stage for Concept Two

5.4.4 Development of the Stages Connections

5.4.4.1 Concept One

Because the goal is to have the blocks in stage one to be played in stage two as well, some issues came out. One issue is thinking about a way to guarantee children only play the pattern blocks in the 2-dimensional way. Because the blocks in the first stage are intended to be used for the second stage, the thickness between these two types of block should be the same. In this case, it's hard to guarantee to have the children at the first stage play in 2D rather than 3D because of the thickness.

An approach was developed to solve this issue. In order to guide children to play in 2-dimensional, using thinner block pieces with half of the thickness of the original block will

achieve a good result. When facing with thinner blocks, children tend to think more ways to play on a surface rather than stacking up. And for having the blocks to be played in the later stage, two identical pieces should be able to connect together and become the same thickness of the original one. Using the magnets is a nice way to achieve that. Also, with the embossed and sunken design for the contact surface, the shape of the combined block is more controllable. The blocks for stage one will ultimately be played on a magnetic board. (see Figure 5.5)

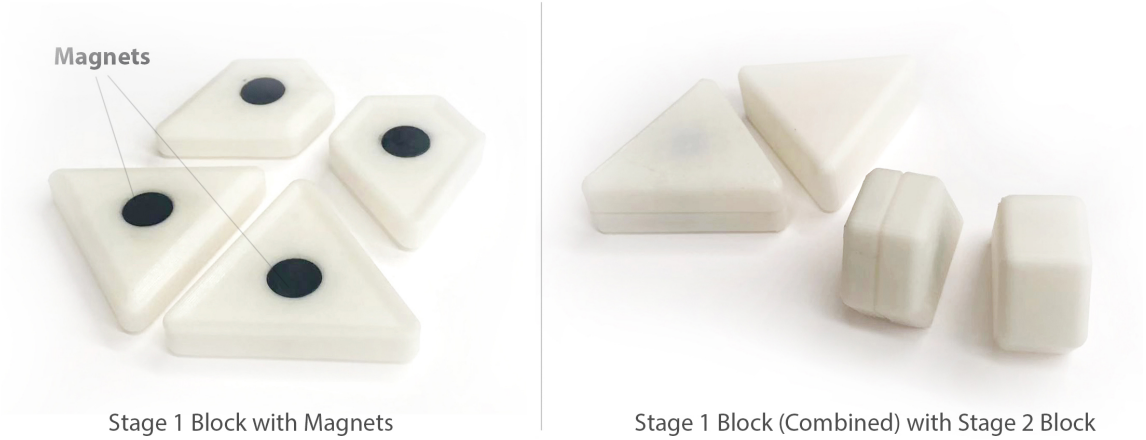

Figure 5. 15 Demonstration of Block Design for Stage One

So the blocks in stage one is one independent product which contains totally eight types and sixteen pieces. The blocks in stage two is also one independent product which contains sixteen types, eight of which are the same as the types in stage one. It's also reasonable to have a module that only contains eight new types of block. When this module is plugged into the product at the first stage, they become a product the same as the product in stage two. Blocks in stage three consisting of into one module rather than a product, because it cannot be played only

with itself. But when this is plugged into the product in stage two, they become a product in stage three.

A concept tree is provided in Figure 5.16. Product 1 represents the product in stage one. Module two represents the eight new types of block. Product two represents the product in stage two with eighteen types of block. It can be either an independent product or consist of product one plus module two. Module three represents the module with 3-dimensional function which needs to be plugged into product two in order to evolve to product three.

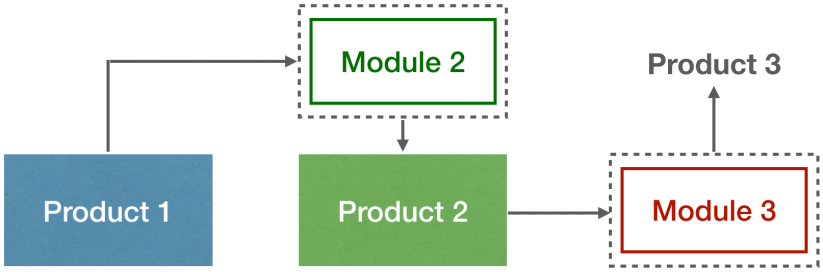

Figure 5. 16 Concept Tree for Concept One

Figure 5. 17 Examples of the Expected Play Outcomes in Each Stages

5.4.4.2 Concept Two

From the first to the second stage, the play in concept two becomes much more complex and sophisticated in 3-dimensional block play. The module that is added in the third stage encourages children to have more story-telling play rather than purely constructive play, which explores a wider play type. The concept tree in concept two is pretty similar to concept one, but the entire system only has one flow. If children want to play with product in stage two, product one and module two need to be there at the same time; if children would like to play in stage three, product one, module two and module three are all necessary.

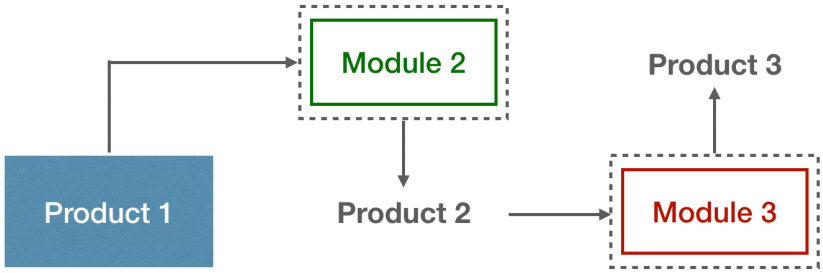

Figure 5. 18 Concept Tree for Concept Two

5.5 Evaluation

First step in evaluation is ability grading. In Table 5.5, all the abilities are graded. All the gradings are based on the performance comparison of two concepts in each ability in different stages.

Using dimensional as an example, according to the development stages of dimensional perception/imagination, children before 5 mainly mastering the 2D perception and imagination. Toys for children in stage one (3 to 4) also need to focus more on this. The blocks in concept one

does a great job for the 2D play while blocks in concept two are paying more attention to the 2.5D and 3D play. And this leads to the points in the first stage being given as 9 and 6. As the second stage, both of these two block toys have done a great job in advanced 2.5D and 3D play. So both got a pretty high score at 9. For the third stage, concept one keeps upgrading the more complex 3D play while concept two changes its focus to another aspect, which leads to a huge drop for its grade.

In the grading chart, several “0” gradings happened because of the absence of certain abilities. In first stage, concept one got three zeros at gravity, social play, and perspective taking, because the magnetic pattern block cannot provide any play associated with the gravity ability or social abilities (only for solitary play). This is the same reason why the concept in stage 3 got a zero in gravity, because the new vehicle, track and character cannot serve the constructive play which deals with gravity.

	Ability		STAGE 1		STAGE 2		STAGE 3	
			Concept 1	Concept 2	Concept 1	Concept 2	Concept 1	Concept 2
Cognitive	Imagination	Dimensional (Perception/Imagination)	9	6	9	9	10	3
		Substitution	8	7	8	8	8	4
	Problem-Solving	Approach (Convergent)	9	4	6	8	7	7
		Outcome (Divergent)	8	8	8	8	9	4
		Logic & Reasoning	8	6	7	8	6	2
	Conservation		8	9	8	9	8	4
	Learning (Attributes & Complexity)	Gravity	0	8	9	10	9	0
		Mathematic	6	7	7	9	6	4
		Shape	8	7	8	9	7	3
Social	Social Play		0	3	3	6	3	8
	Perspective Taking		0	0	2	5	2	5
Motor	Manipulation	Grasping	9	10	9	10	8	3
	Visual Perception	Visual-motor Coordination	7	10	8	10	9	4

Table 5. 5 Graded Table with Value

The second and the third step is calculation. Table 5.6 shows all the converted scores and the calculated sum score in percentage.

And Table 5.7 shows scores in each stage and the average final scores for these two concepts. It is easy to notice that scores in concept one are more close to each other and the scores in concept two are differentiated dramatically. If designer needs to improve these two concepts, for concept one, the first stage is priority; for concept two, the third stage is priority. But if a choice needs to be made from these two concepts, concept one should be the one developed for the final delivery.

	Ability		STAGE 1			STAGE 2			STAGE 3		
			3-4	Concept 1	Concept 2	4-7	Concept 1	Concept 2	7-8	Concept 1	Concept 2
Cognitive	Imagination	Dimensional (Perception/Imagination)	1	0.9	0.6	2	1.8	1.8	1	0.8	0.3
		Substitution	1	0.8	0.7	2	1.6	1.6	3	1.8	1.2
	Problem-Solving	Approach (Convergent)	1	0.9	0.4	1	0.6	0.8	2	1.4	1.4
		Outcome (Divergent)	2	1.6	1.6	2	1.6	1.6	3	2.7	1.2
		Logic & Reasoning	1	0.8	0.6	1	0.7	0.8	2	1.2	0.4
	Conservation		1	0.8	0.9	1	0.8	0.9	2	1.6	0.8
	Learning (Attributes & Complexity)	Gravity	1	0	0.8	1	0.9	1.0	1	0.9	0
		Mathematic	1	0.6	0.7	1	0.7	0.9	2	1.2	0.8
		Shape	2	1.6	1.4	1	0.8	0.9	3	2.1	0.9
Social	Social Play		1	0	0.3	2	0.6	1.2	3	0.9	2.4
	Perspective Taking		2	0	0	1	0.2	0.5	3	0.6	1.5
Motor	Manipulation	Grasping	1	0.9	1.0	1	0.9	1.0	3	2.4	1.8
	Visual Perception	Visual-motor Coordination	2	1.4	2.0	2	1.6	2.0	1	0.9	0.6
SUM			17	10.3	11	18	12.8	15	29	20.1	13.3
Score				60.6%	64.7%		71.1%	83.3%		69.3%	45.9%

Table 5. 6 Score Converting Calculation

	Design 1	Design 2
STAGE 1	60.6%	64.7%
STAGE 2	71.1%	83.3%
STAGE 3	69.3%	45.9%
Avg.	**66.8%**	**64.6%**

Table 5. 7 Average Score Calculation

5.6 Final Delivery

In this application, the toy type is block toy with the age range of 3 to 8. The age range was decomposed into three stages, from 3 to 4, from 4 to 7, and from 7 to 8. The modular system contains two independent products and two dependent modules. The relationship was shown as below (see Figure 5.19). The design considered children's ability development at different stages. The abilities are dimensional comprehension and imagination, substitution, approach, outcome, logic and reasoning, conservation, gravity, mathematic, shape, social play, grasping, visual-motor coordination (see Table 5.8). The ability attributes were shown in Table 5.9.

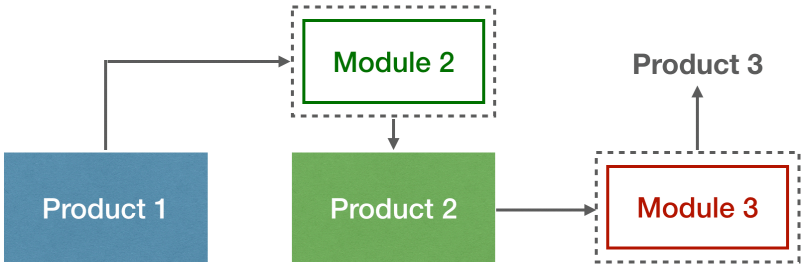

Figure 5. 19 Concept Tree

	Ability		3-4	4-5	5-6	6-7	7-8
Cognitive	Imagination	Dimensional (Perception/Imagination)					
		Substitution					
	Problem-Solving	Approach (Convergent)					
		Outcome (Divergent)					
		Logic & Reasoning					
	Conservation						
	Learning (Attributes & Complexity)	Gravity					
		Mathematic					
		Shape					
Social	Social Play						
	Perspective Taking						
Motor	Manipulation	Grasping					
	Visual Perception	Visual-motor Coordination					

Table 5. 8 Ability Developing Table

	STAGE 1	STAGE 2	STAGE 3
Dimensional (Perception/Imagination)	Product 1	Product 2	Module 3
Substitution	Product 1	Product 2	Module 3
Approach (Convergent)	Product 1	Product 2	Module 3
Outcome (Divergent)	Product 1	Product 2	Module 3
Logic & Reasoning	Product 1	Product 2	Module 3
Conservation	Product 1	Product 2	Module 3
Gravity		Product 2	Module 3
Mathematic	Product 1	Product 2	Product 2
Shape	Product 1	Product 2	Module 3
Social Play		Product 2	Product 2
Perspective Taking		Product 2	Module 3
Grasping	Product 1	Product 2	Module 3
Visual-motor Coordination	Product 1	Product 2	Module 3

Table 5. 9 Ability Distribution Chart

Chapter 6 Conclusion

6.1 Conclusion

The intention of this thesis was to develop an approach to help designers design the toy with a longer serving time. The focus is the development of children's need and ability in different ages. The tool is modularity and the object is an open-ended toy. Through the study, the relationship between play and children development is discovered, and the cognitive, social and motor development were further researched for the later use of criteria table development. Open-ended toy was defined in the massive toy types. Modular thinking and modularity principles were studied. A ability table with the development of children's abilities is defined for designers to study in the research period. An evaluation method was developed in the study for evaluating different concepts in a more objective and rational way.

6.2 Further Development

Extending the toy's serving time has several directions. This research is focusing more on the study of children's need and the toy's functionality. There are still more possibilities out of this topic, such as emotional aspect. There are already some research talking about the adult's emotional connection with objects and products, but currently no children's perspective. It will be worth to develop that unexplored field.

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