Design Approach of Adaptable Residential Space Design with Childhood Development

by

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Abstract

Children's room design for a specific age period is a mature field. However, few children room designs will consider the adaptability of the room. Creating a room that could grow with children is necessary.

This thesis discusses the design approach of creating a residential space that grows with children. It can meet different needs in diverse age periods. Children's needs in distinct age periods are various. The thesis provides information from adaptable room design, childhood development, and children room design in the literature review. Based on the research, the thesis provides two essential viewpoints, which is the fundamental thinking for creating the design method. They are the order of children age division and children ability selection.

Depending on the literature review and the two vital perspectives, the design approach is formed. There will be three phases of the design approach. They are the preparing phase, design phase, and construction phase. After the design approach, the thesis would introduce a design application to provide an example of utilizing the design approach.

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Chapter 1 Introduction

1.1 Problem Statement

According to observations of the modern family, the children's room will likely be kept invariable for most of childhood. The same living space layout will accompany children's development from birth to adults. Sometimes, when children grow to an upper age period, the original space design may not meet their advanced demands physiologically and psychologically. The children's room may even show less relationship with and reflection on a child's development. Thus, if children's residential space could be adaptable, it will be better fit children's development.

Thinking about the reason why the development of the children's room is essential, there are three main reasons. First, children spend a lot of time at home. Research shows that about a third of preschool children spend more than seven hours in the daycare, while the rest of time will be spent at home (Capizzano, 2000). Also, adolescents spend about 60% of the week at home (American time use survey, 2013), not to mention they spend more hours on mobile screens which includes TV, video games and computers. All of these activities will normally happen in the home (Howard, 2017). Second, the space environment plays a vital role in children's development. A pleasant environment brings a positive effect on children. As architect Peter Zumthor said about his childhood memories in Switzerland, "Memories like these contain the deepest architectural experience that I know. They are the reservoirs of the architectural atmospheres and images that I explore in my work as an architect" (as cited in Dobbins, 2018). On the contrary, a poor space environment can bring a negative effect on children. Poor quality

material would bring indoor air pollution which can cause respiratory illness. Defective furniture design can also affect children's body development. Chaotic color arrangement may result in irritability which influences children's academic performance. Third, childhood development has its special sensitive periods which promote children to cultivate specific behaviors. Missing some of these sensitive periods will cause the loss of some abilities which can be hard to shape in the future. According to the research, the children who receive little individual attention and sensitive care before age two get lower IQ scores than the children who get enough stimulation before the same age. A proper environmental design would provide enough stimulation for children to help them develop. Depending on the three main factors, it is concluded that the flexible space design has the potential to benefit childhood development.

Even though the home space is so essential for children, parents could inadvertently neglect that space needs to grow with children. This disregard can be attributed to both children and parents. For children, their physical and psychological features change rapidly and prominently. Their demands for the space in which they live also explicitly changes. Thus, it is hard to ascertain accurate demand and offer proper care. Also, before children have mature speaking skills, it is hard for them to express their demands or needs. For parents, the decorating and design for a child's room is often for one particular period. Even though parents would like to redecorate and redesign children's space, it might cost more money, time and energy than they are able to spare.

However, there are sufficient reasons for a family to prepare a flexible space for their children. First, many families have a preference for home improvement. According to the

American Housing Survey (2013), many homeowners would like to improve their homes, rather than move to a new home. Also, they like to make their home efficient. Reporters (2013) state that 63% of homeowners prefer to make improvements by professionals, which means that they might need the designers to offer a professional scheme. Second, many families would accept the form of the adaptability of space. Rybczynski (1991) claims that many American families believe that their homes would last their lifetimes. This kind of thought would help them to accept the idea of adaptable space. Also, a global economic recession would likely strengthen the need for alternative forms of housing. They are affordable and flexible enough to meet the needs of the evolving American family in a new, learner economy (Nichols, 2013). Third, compared to the past, modern parents today would like to pay more attention to the environment of raising children. Many young couples today are postponing marriage or children until economic conditions improve (Nichols, 2013). They would likely pay more for their children to improve their abilities. “A middle-income, married couple with two children is estimated to spend $233,610 to raise a child born in 2015”, according to a report released by the Department of Agriculture (as cited in Vasel, 2017).

In summary, it is essential to pay attention to the development of children’s room. If the living space can have proper design and plans, it can become a supportive home which could help children to get adequate rearing in different age periods.

1.2 Need for Study

In the market, designers do care about childhood development and the adaptability strategy. There exist multiple approaches to create designs that can meet children's various demands, or a versatile system that can fit the multifunctional requirement.

Age-appropriate adaptable furniture is furniture which can be updated for new purposes as children grow up. There exists a great market potential in this field of furniture. Adjustable furniture has many advantages. It could meet children's needs in different development stages, reduce the waste of resources and save more space. For example, the chair designed by Permafrost Design Studio could be used from birth to adulthood. It is a highly versatile and user-friendly modular system. Also, another example is a combination of bed and table. The "Illa and Illeta" was designed by Dutch brand Teehee. It includes a bed, a table, the shelves, and a hanging rail. All of these pieces can be converted into different functions when small users grow older (Tucker, 2016). According to the research of the furniture company Lifetime (2018), it concluded four features about the children's adaptable furniture. The first feature is adjustability, which helps the furniture to fit children's physical development. The second feature is modularity, that provides furniture the opportunity to be deconstructed and reassembled to form furniture with a new function. The third feature is a combination of repetition. The fourth feature is multi-function. Single furniture mixes different functions to meet different needs in the same period. For the most part, the goal of adaptable furniture is using limited resources to achieve the combination, variation, and transformation of different functions. However, if the designers fail

to grasp the fundamental characteristics of physiological and psychological changes in children development, adaptable furniture might not provide proper functions for children's activity.

Figure 1.1 Permafrost Adaptable Furniture

Figure 1.2 Teehee Adaptable Furniture

In addition, adaptable toys get much attention in today's market. These kind of toys will provide high quality and multifunctional toys that can accommodate all ages. They are also designed to deal with toy waste and toy abuse (Liu, 2018). The building and construction toys from Lego are good example. The different blocks and pieces allow children to create "infinite building outcomes with only one set." The Lego system also allows "different sets to fit together for building a more complex creation" (Liu, 2018, p. 89). The adaptable toys use the idea of a modular product system which can be transformed from one function to another new function.

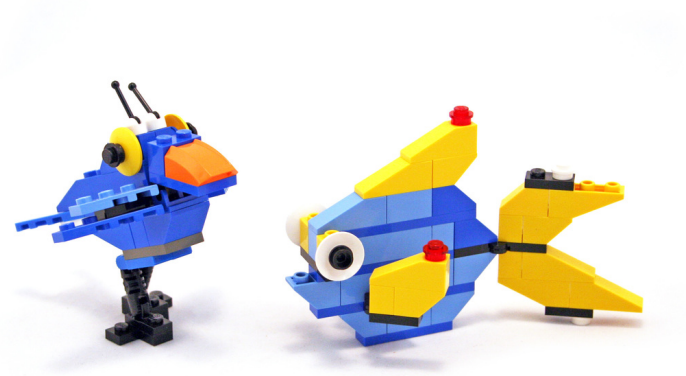


Figure 1.3 LEGO Multiple Build Set

Moreover, the experiment involving flexible space has never stopped. The earliest adaptable housing emerged after the Second World War. At first, it aimed to meet "the need to house a large portion of the population efficiently and cost-effectively." However, with the development of the conventional mass house, adaptable space begins to serve "the diversity needs of the individual" (Friedman, 2002, p. 19). Also, the adaptable house benefits the families.

For example, in 1970, an adaptable house project, which was the first undertaking of the KEP (Kodan Experimental-housing Project), was built in Tama New Town, a suburb of Tokyo. It was designed with several movable partitioning systems to meet the family's changing requirements. After decades, when researchers revisited these families, they found that even though the movable system had some technological problems, many of the families did use the system and benefited from it. As children grew, and when they left home, many families used the KEP partitioning system to adjust the room arrangements to fit the changes in their lifestyles. The KEP system appears to have worked the way it was planned to more than twenty years ago (Minami, 2007).

In this research, it was found that the three types of design work respectively show a part of solutions on the problem about how to design an adaptable space for children's room. The adaptable furniture and adaptable toys offer children a potential future, but have little relationship with the environment. The adaptable housing design serves to the open space, but it fails to achieve the adaptability in a single room. The design of an adaptable children's room is a combination of childhood development and adaptable house design. If designers could extract from their grasp of childhood development into versatile furniture and the methods to make space flexible in adaptable house design, then they could potentially create the age-appropriate adjustable children's room.

1.3 Objective of Study

- To study the adaptable room design.
- To extract the design strategies in existing adaptable space design solutions.

- To study the influence of the space on children.
- To study childhood development in different aspects between 0-18 years old.
- To define children's demand of 0-18 years old.
- To determine the relationship between adaptable room design, environmental variation, and childhood development.
- To develop a guideline for residential space design which is adaptable for childhood development.

1.4 Definition of Terms

Adaptable - Capable of being or becoming adapted ("Adaptable," n.d.).

Configuration - Relative arrangement of parts or elements: such as functional arrangement ("Configuration," n.d.).

Development - The act, process, or result of developing ("Development," n.d.).

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

Interior Design - The act or practice of planning and supervising the design and execution of architectural interiors and their furnishings ("Interior Design," n.d.).

Spatial - Relating to, occupying, or having the character of space ("Spatial," n.d.).

1.5 Assumptions of Study

It is assumed that all the research, information and data I found are reasonable and accurate.

It is assumed that the children whom this design tool aims to help have their own room in their home.

It is assumed that the children's space could be adapted.

It is assumed that parents care about their children's development.

It is assumed that children's development can be improved with space design.

1.6 Scope and Limitations

First, the selection of children's space is limited. As mentioned above, the studies in public indoor space for children have been thoroughly discussed, but the residential space for children are seldom investigated. Thus, the thesis will not involve the study of public interior design for children. Furthermore, even though this design tool is intended to be a universal design guideline which could be applied to all room types, different family composition, and different children's demands, some special situations would not be considered and studied in this research. The particular situations might include but not be limited to the particular living conditions (such as refugee camps), the children with special needs, diverse lifestyles, multiple cultural attitudes, and various religious beliefs. These special situations are more complex and should be discussed in further study.

Second, the selection of childhood development is limited. Childhood development is an essential part of the thesis. Only parts of the children's abilities which might be influenced or improved by the space design will be discussed in the thesis. The other vital children's abilities which will not be enhanced by the space design will not be mentioned in the thesis. Proper space

design could help children to develop, but it will be not the primary improvement for the childhood development.

Third, the benefits for children are limited. Moreover, the design guideline will not provide methods about how to correct children's behavior or tips about how to educate children in their academic performance. It only provides a guideline to design a flexible living space. Also, this living space will grow to fit children's varying demand for different age periods.
In summary, this thesis mainly devotes to study a overlooked area: the residential space does not grow with children. To fix this defect, the thesis investigates flexible room design and children development and tries to find the relationship between them. Space should not be isolated, and it should be a living being which could create informal communication with children. Also, the limitations which are mentioned before do exist. Even though they are outside the scope of this article, they should get attention from designers.

1.7 Procedures and Methodology

Procedure 1: Study the theory of childhood development.

• Researching the outline of childhood development in library and online resources.

• Researching every aspect of childhood development in library and online resources.

Procedure 2: Study the theory of adaptable housing design.

• Studying the definition of adaptable housing design.

• Studying the construction and systems in the adaptable room.

• Studying the interior space and utilities in the adaptable room.

Procedure 3: Study the existing indoor space design for children.

• Collecting the cases of indoor space design for children.

• Analyzing the cases of indoor space design for children.

• Extracting the design methods that could be used in adaptable space design.

Procedure 4: Develop the guideline of how to use adaptable interior design to fit childhood development.

• Confirming the research methods.

• Confirming the design process.

• Predicting the possible final delivery.

Procedure 5: Apply the design guideline into a real interior system design.

1.8 Anticipated Outcomes

With children develop from birth to adults, their living space also needs to be altered to fit their varied demands in both physiological and psychological aspects. However, according to the observation of the modern family, parents often pay little attention to the change needed in the children's room. Thus, the primary goal of the thesis is to find a approach to create an interior environment which could be adaptable for children development. Designers can use this approach to achieve the goal of creating adaptable children space. The final delivery will be an interior design and the instruction of its possible future changes.

Chapter 2 Literature Review

2.1 Adaptable Room Design

This section will discuss the definition, theory, history and principles of adaptable housing design. This can help designers to understand the tools that will be used in the design approach.

2.1.1 Definition of Adaptable Room Design

The adaptable house is a term that describes one particular form of house. There are many other concepts of this particular form of the house: adjustable house, transforming house, versatile house, livable house, developed house, modular space, multitasking space, and hybrid space. Under different historical background and in different countries, the experiment of the adaptable house served different housing types and aimed to meet different goals. From the past to current society, the adaptable house constantly evolved and changed, and it gains new meanings in every period.

In the following paragraphs, the evolving mission of adaptable house in the different periods will be discussed in detail. In summation, based on the interpretations mentioned above, a new conception which will be used in this thesis will be created.

The definition in history: There are two primary turning points in the history of the adaptable house. The historical background in the first point established the necessary housing type that allowed the versatile design to happen in the future. Moreover, in the second point, a series of changes in the world triggered the final emergence of adaptable house (Friedman, 2001).

The first turning point happened in the period of the Industrial Revolution. By the mid-18th century, with some critical industrial technology developed, the technical progress improved the building construction which set the foundation of the flexible building. The technology also brought some social effects. With the change of family composition, the rise of low-income house, the increase of population, the development of urbanization and the promotion of commercialization of housing, home mobility merged. The government encouraged the production of mass-housing which drove the production of small and limited space (Friedman, 2002)

The second turning point happened in the period after the Second World War. Under the background where society rapidly changed, conventional mass-housing strategies were challenged by both sellers and buyers. The monotonous mass-housing gradually cannot satisfy the diverse needs and particular requirements of the individual. The experiments of the adaptable house happened in both America and Europe. However, the goals of architects in the two places are different. In America, with the rise of suburbs, change of the family size, and advent of consumerism, a new lifestyle emerged. However, new housing projects were still limited to the price and size by the government. These constraints forced designers to "investigate the innovative strategies as well as to attempt to respond to the needs of the occupants with maximum efficiency" (Friedman, 2002, p. 20). Then, with the baby boom and veterans returning from World War II, market houses were designed smaller, which could be sold quickly, efficiently, and cheaply. The goal of the adaptable house in this period of America was trying to solve the problem of small spaces in low rise, low density and wood frame suburban projects. At

the same time in Europe, European architects proposed two concepts of adaptability, which are pre-occupancy adaptability and post-occupancy adaptability. They were trying to humanize the house. The goal of the adaptable house in this period of Europe was aimed to recreate the identity of mid-rise, high-density and concrete structures dwellings (Friedman, 2001).

The development of flexible houses did not last long; an abandonment quickly happened. In North America, with economic prosperity, buyers could afford large houses. The function of flexible rooms was regarded as unnecessary. Also, in Europe, the financial support of the experiments on the flexible house from governments declined. People were no longer pursuing a flexible house (Friedman, 2002). However, there still exist new opportunities and futures in the flexible housing design. People will be still eager to have flexibility and segmentation in their house instead of homogeneity. A new concept about the adaptable house is from the Industrial Version. The new concept will include not only flexible arrangements of interior volumes but also prefabricated systems (modular, the kit of parts, and panelized system) and subsystems (walls, floors, and roofs). The combination of these industrial parts will finally form a complete package system (Wylde, 1994).

Definitions from Different Theorist: Avi Friedman and Witold Rybczynski (1991) developed the concept of "Grow Home" in 1990 at Montreal's McGill University. They proposed that the definition of a grow house should be providing occupants with forms and means that facilitate a fit between their space needs and the constraints of their homes either before or after occupancy. These housings were constructed for low-income users. The other similar flexible housing model was created by Sevag Pogharian, which was the "Sprout Home" (CMHC, 2012).

Pogharian defined the home as “a house that could be progressively completed like the grow home, but with a full-size basement and additional attic space to expand into” (Nichols & Adams, 2013, p. 40). Both the Grow Home and Sprout Home provide families the adaptability in house to meet their requirements. The drawbacks to Pogharian, Friedman, and Rybczynski’s flexible home designs are that they must be newly built housing, and “require land and site development” (Nichols & Adams, 2013). There are also Next Home and Suburban Retrofit which provide more variations of flexible housing design.

Moreover, the adaptable housing design is also subdivided to fit user’s special needs. Wylde’s theory and practice tend to create an elder's adaptable system from an industrial design version. She emphasized that the adaptable living environments should conform to the needs and abilities of the occupants at any age.

The Adaptable Room: As discussed before, the meaning and goal of adaptable homes changed with social development. This thesis will focus on the adaptable design within a room which is a part of a house. Also, this adaptability aims at children development. Thus, the definition of the adaptable children room could be redefined as space that is designed for adjustment over children development and can be adapted as children grow. The adaptable room will be a branch of the adaptable house, which means the strategies applied in the adaptable house could also be used to achieve the flexibility of children’s room. Considering every change in the room needs to have an explicit purpose, the design process might be further complicated.

2.1.2 Interior Adaptability Principles

The principle of interior design corresponds to the whole house design. Even though this thesis is talking about interior design in one room, it could refer to the basic principle applying to the whole house interior design.

2.1.2.1 Manipulation of Spaces

Principal Function Zone: The Definition of Function Zones in architecture is "Referring to how the overall space of a dwelling unit can be arranged according to zones (e.g., public, private, daytime, nighttime) to allow a greater degree of adaptability" (Friedman, 2002, p. 124). The definition of Function Zones in interior design is often related to the divided area in the whole house. The divided area usually includes public area, semipublic, or private areas. In this section, we would discuss functional zones in a relatively micro scale. The children's room is a private area as a part of the functional zones in the whole house. According to the different primary activities, the private area could also be divided into different functional zones like sleeping area, study area, and playing area. The placement of zones would influence the room adaptability and the overall layout. They might be improved or switch to other functions later as kids grow older. The different activities that happened in a room would decide the type of function zones, the size of each zone, the arrangement and the possible future overhaul of these zones.

Auxiliary Function Zone: Besides the principal activities in a room, there are also some auxiliary spaces. It is essential to analyze and make a distinction between these two types of activities. The main activities would have their furnishings and arrangement. However, the space

allocation for the auxiliary activities is easily ignored, not like the major area which will remain the same for a long time. Reserving the space for auxiliary activities would not only meet users' varied requirements but also offer opportunities for future transformation. The auxiliary space would include but not be limited to the storage area, office area, social area, and clean area (Friedman, 2002).

Spatial Strategies: The meaning of spatial strategies is permitting space to be easily adaptable at a macro level. At this point, some unique spatial configurations should be considered in advance. For example, the open space could function as a strategy to change the size and trend of whole space. It always depends on the dwelling type. Breaking the nonbearing walls often provides the opportunity to expand the space. Setting multipurpose spaces is also a way to make space flexible. A room might have some permanent interior features which would affect its function. Designers could eliminate these identifying features and create other possible uses. Moreover, another strategy for adaptability is making furniture as partitions or walls. The using of furniture could subdivide spaces and create distinct functions in space. Bookshelves or closet components are all good space dividers. The various height, function, and location of furniture would solve diverse space issues and build different space effect (Friedman, 2002).

Access and Circulation: The access includes doors which means the entry into a room and windows which represent the social interaction with the outside world. Circulation represents the area that people can reach different functional zones. All the access and circulation would affect room adaptability. The location of doors and windows would affect the arrangement of the room plan. Also, people would like to pursue efficient circulation inside a

room. Designers would try to reduce the circulation area or add another function to it. (Avi, 2002)

2.1.2.2 Manipulation of Subcomponents

Pre-manufactured Components: From the industrial version, installing and using pre-manufactured components could be another way to achieve adaptability in the home's interior. It mainly includes demountable partitions. The demountable partition has three central wall systems. The first one is the Mobile System. The system would allow the wall panels to move with ceiling tracks with the sliding mechanism. The second system is the Demountable System. It has pre-finished wallboards which are affixed with metal frame and placed at specific intervals. The third one is the Portable System. The prefabricated panels are bought to the desired location and held in place by channels in the ceiling and doors (Friedman, 2002).

Furniture and Utilities: The flexibility, the placement and the access of home's interior utilities and furniture would also affect room adaptability (Friedman, 2002).

Surface Finished: Surface finishing needs to be considered as another factor that would affect the room adaptability. The room surface would include but not be limited to interior partitions, wall covering, floor covering and ceiling (Friedman, 2002).

2.1.2.3 Growth and Division

Vertical Expansion: The high ceiling or the pitched roof could provide an opportunity that makes a change in floor level. Introducing a Mezzanine might produce a level difference, and create new space for more functions. Usually, a minimum height of 16 feet (4.9 meters) is required for this aim (Friedman, 2002).

Horizontal Expansion: The function of expansion is similar to the open space. When children need more space, new space is available and breaking the walls are permitted, unused indoor spaces could be added into this room to explore the possibility of adaptability design. Especially when children grow up, they might need more open space which is better connected with their main bedroom. These kinds of space could be a hobby room, a storage room or a study room (Friedman, 2002).

2.2 Childhood Development

This section will mainly discuss different aspects of children development. It will include children's physical development, motor development, perceptual development, social emotional development, cognitive development, and sensitive period development. At the final of this chapter, there is a conclusion section, which has a research method defined. This section will introduce the age selection method and ability selection principle. These methods will be used in the design approach in the next chapter.

2.2.1 Physical Development

Body Size Development : At the beginning of life, the babies' size change is dramatically huge and rapid. From birth to the end of the first year, babies will increase an average of about 11 inches in length. From the first year to the second year, the rate of growth becomes lower than the first year, but it still keeps an average increase about six inches in length. Babies have the most significant growth in the first few months. However, the growth rate dramatically declines from the middle of the first year to the end of the second year. From age

two to age three, babies' height increase rate keeps declining, but the weight increase rate remains unchanged.

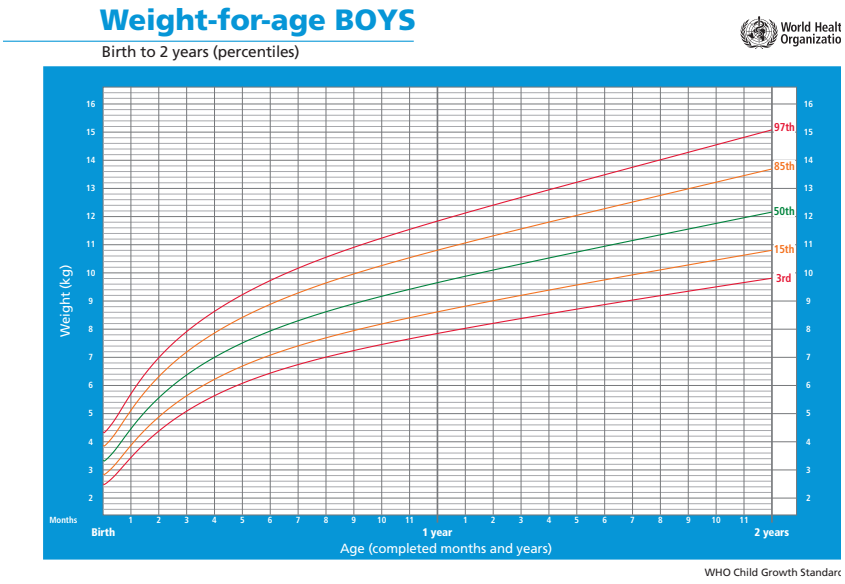


Figure 2.1 Boys Infants Weight (World Health Organization, n.d.)

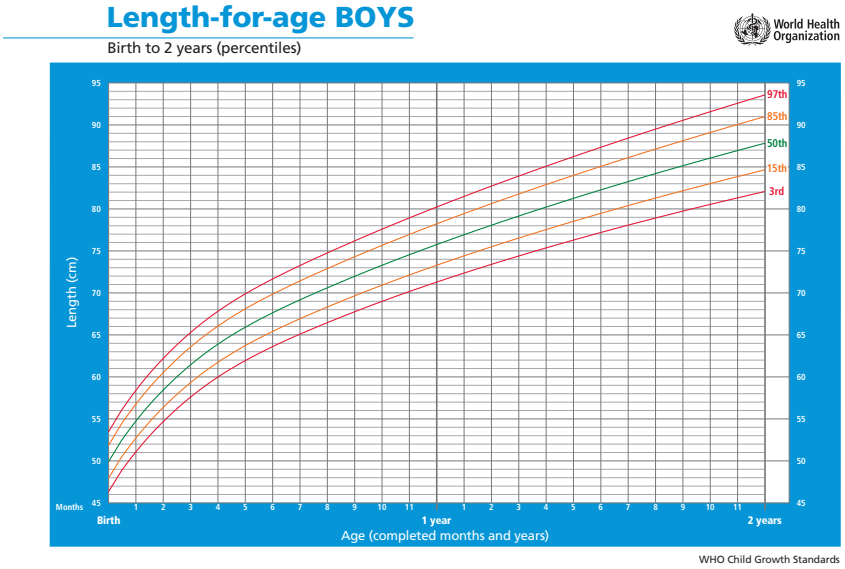


Figure 2.2 Boys Infants Length (World Health Organization, n.d.)

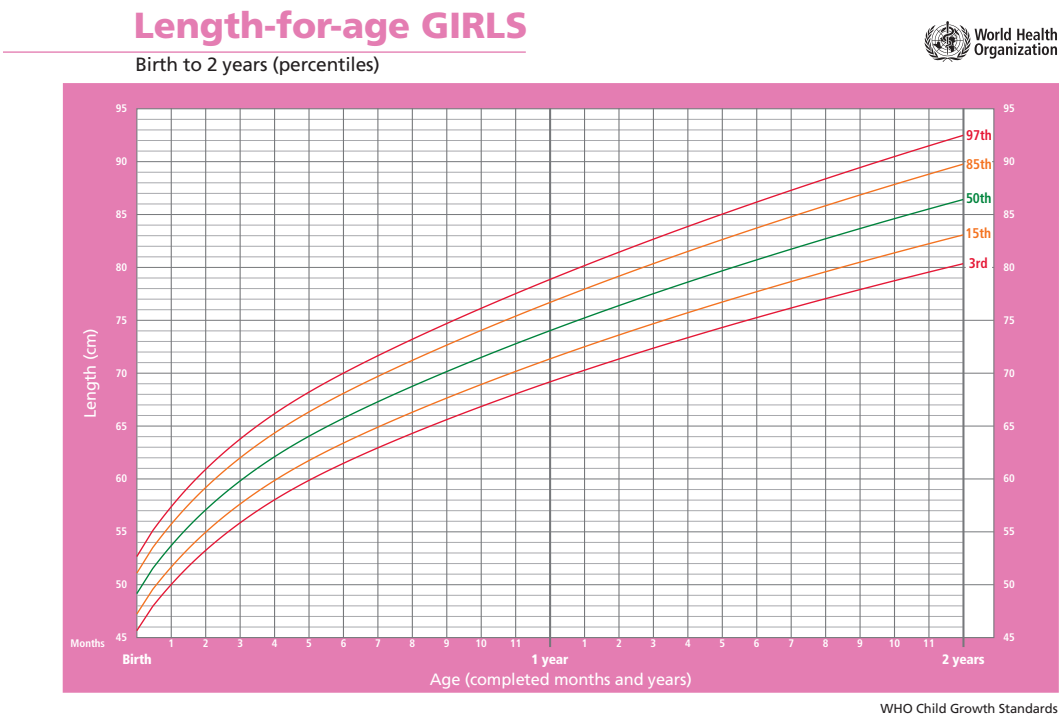


Figure 2.3 Girls Infants Length (World Health Organization, n.d.)

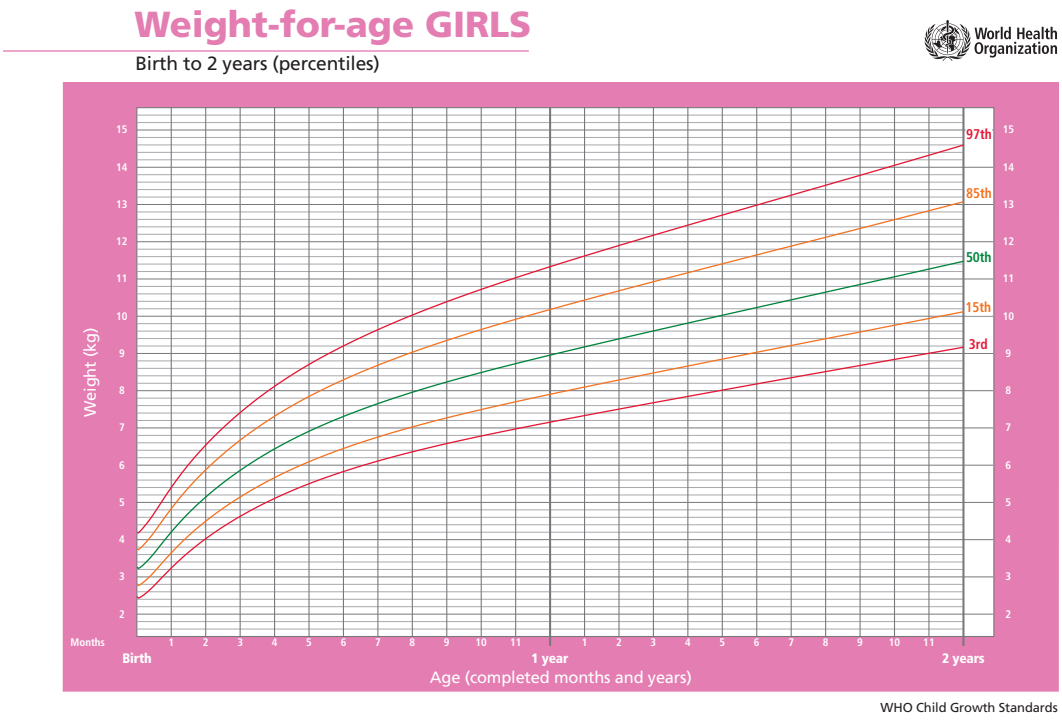


Figure 2.4 Girls Infants Weight (World Health Organization, n.d.)

During early childhood, children grow more slowly than in the infant and toddler period. The growth rate of height about both girls and boys continues to decrease, but the growth rate of weight about girls and boys begins to increase. According to the health statistics from Centers for Disease Control and Prevention (CDC, 2000), at the age three, the average height of boys is 37.5 inches, and the average height of girls is 37 inches. At the age of four, the average height of boys is 40.5 inches, and the average height of girls is 39.5 inches. At the age of five, the average height of boys is 43 inches, and the average height of girls is 42 inches. At the age of six, the average height of boys is 45.5 inches, and the average height of girls is 45 inches.

In this period, the growth speed keeps slow like early childhood. The height growth rate remains declining from age six, and at the about age eight, the growth rate is about two inches which is the lowest point. For girls, the height rate begins to increase from age eight and reach the highest point at around age twelve. For boys, the growth rate will keep slow during early childhood.

According to the health statistics from Centers for Disease Control and Prevention (CDC, 2000), at the age seven, the average height of boys is 48 inches, and the average height of girls is 47 inches. At the age of eight, the average height of boys is 50.5 inches, and the average height of girls is 50.5 inches. At the age of nine, the average height of boys is 52 inches, and the average height of girls is 52.5 inches. At the age of ten, the average height of boys is 54.5 inches, and the average height of girls is 54.5 inches. At the age of eleven, the average height of boys is 57 inches, and the average height of girls is 56.5 inches. At the age of twelve, the average height of boys is 59 inches, and the average height of girls is 59 inches.

At the period of puberty, boys will have a sharp acceleration in the rate of growth again. At around the end of thirteen years old, boys reach a high point of growth rate. After thirteen years old, both the growth rate on girls and boys go down and ultimately stop at around age eighteen. According to the health statistics from Centers for Disease Control and Prevention (CDC, 2000), at the age 13, the average height of boys is 61 inches, and the average height of girls is 61.5 inches. At the age of 14, the average height of boys is 65 inches, and the average height of girls is 63 inches. At the age of 15, the average height of boys is 68 inches, and the average height of girls is 64 inches. At the age of 16, the average height of boys is 68.5 inches, and the average height of girls is 64 inches. At the age of 17, the average height of boys is 69 inches, and the average height of girls is 64 inches. At the age of 18, the average height of boys is 69.5 inches, and the average height of girls is 64.5 inches. At the age of 19, the average height of boys is 70 inches, and the average height of girls is 64.5 inches.

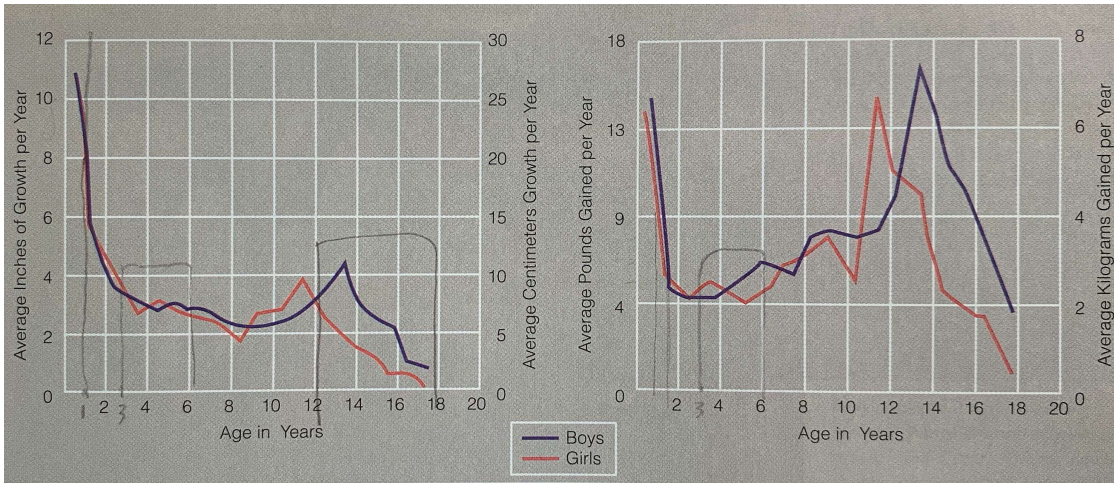


Figure 2.5 Height and Weight Velocity from 0 to 18 years old (Berk, 2000, p. 175)

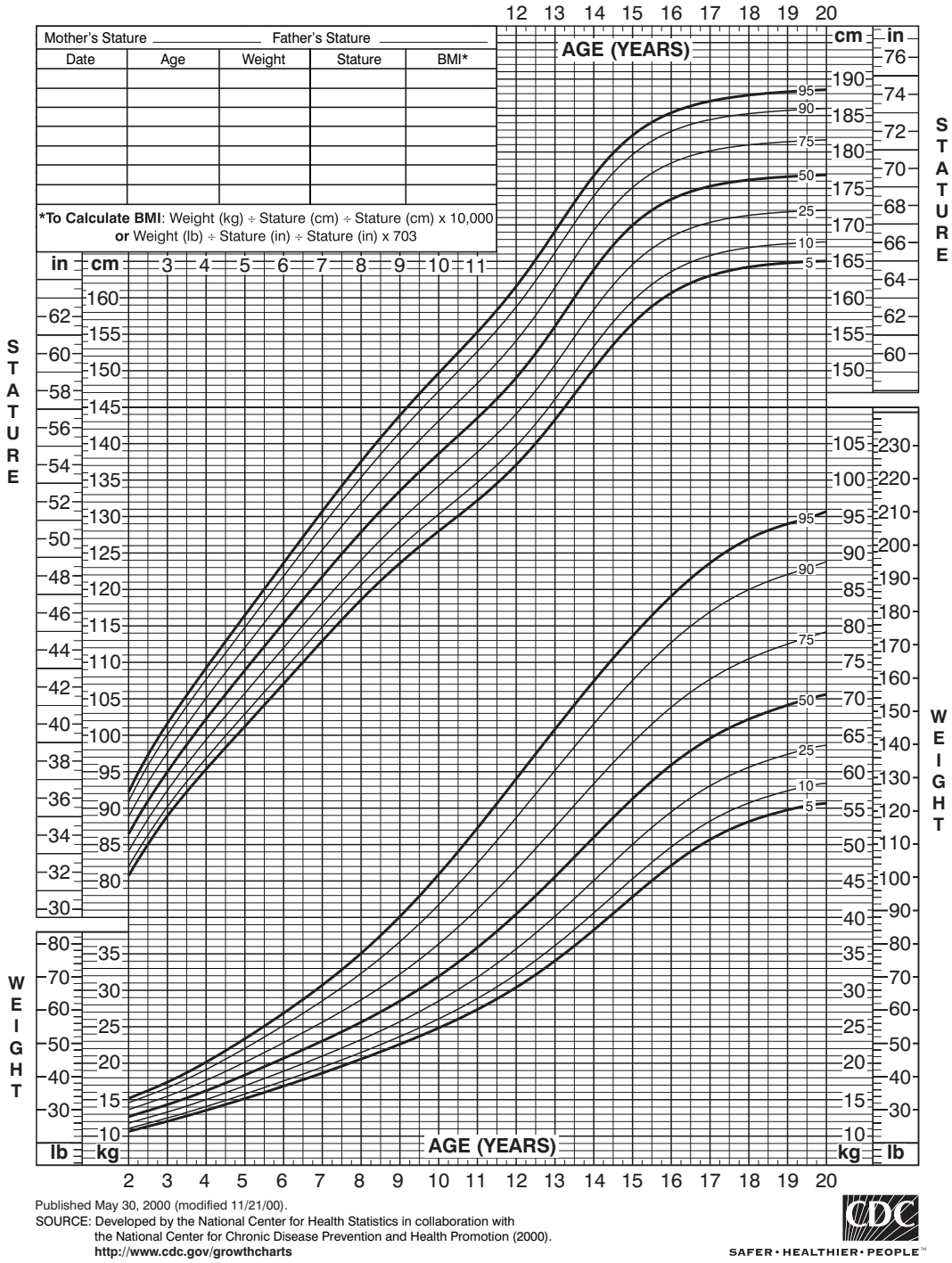


Figure 2.6 Boys Length and Weight from 2 to 20 years old (CDC, 2000)

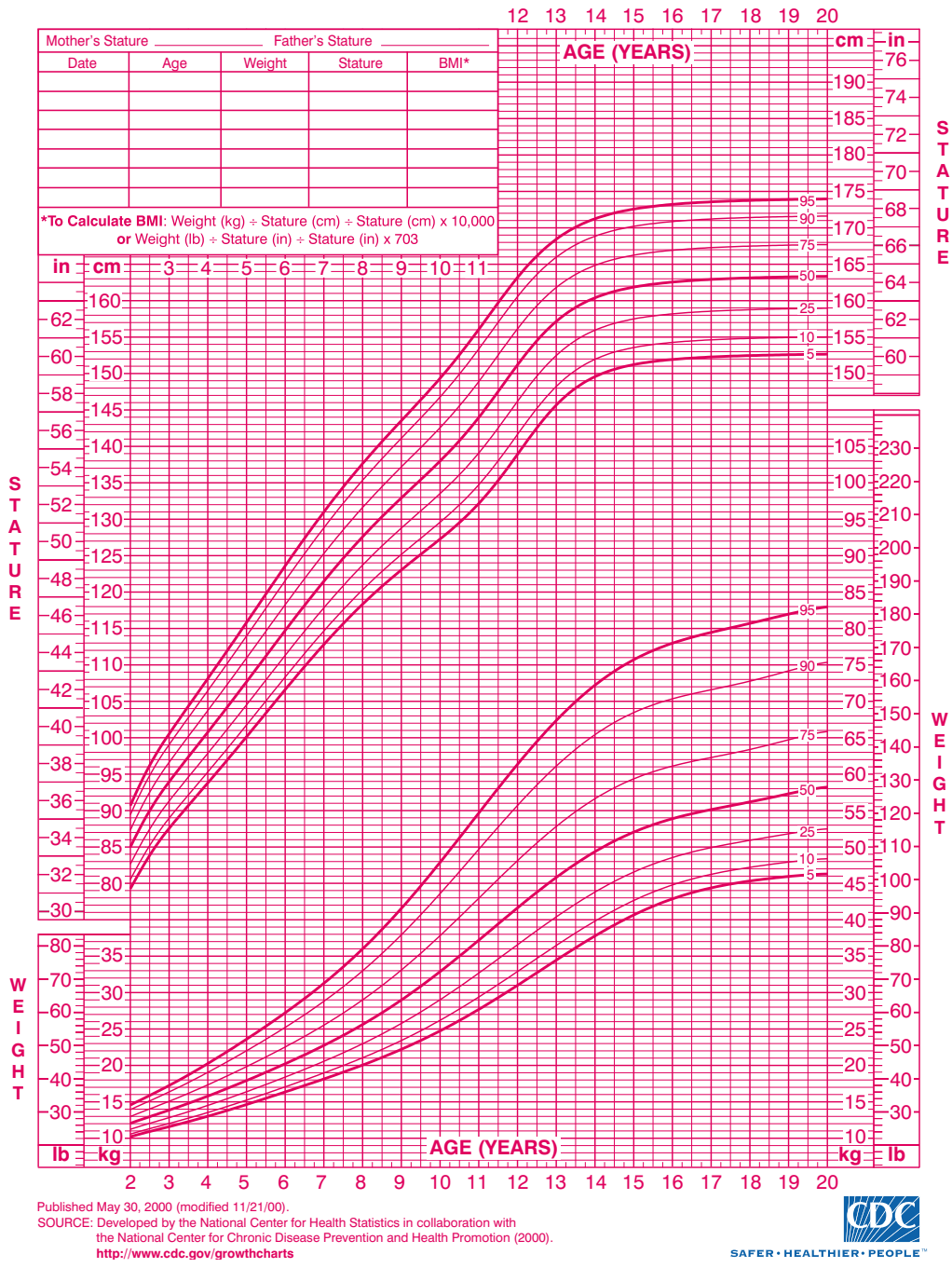


Figure 2.7 Girls Length and Weight from 2 to 20 years old (CDC, 2000)

Seated Height

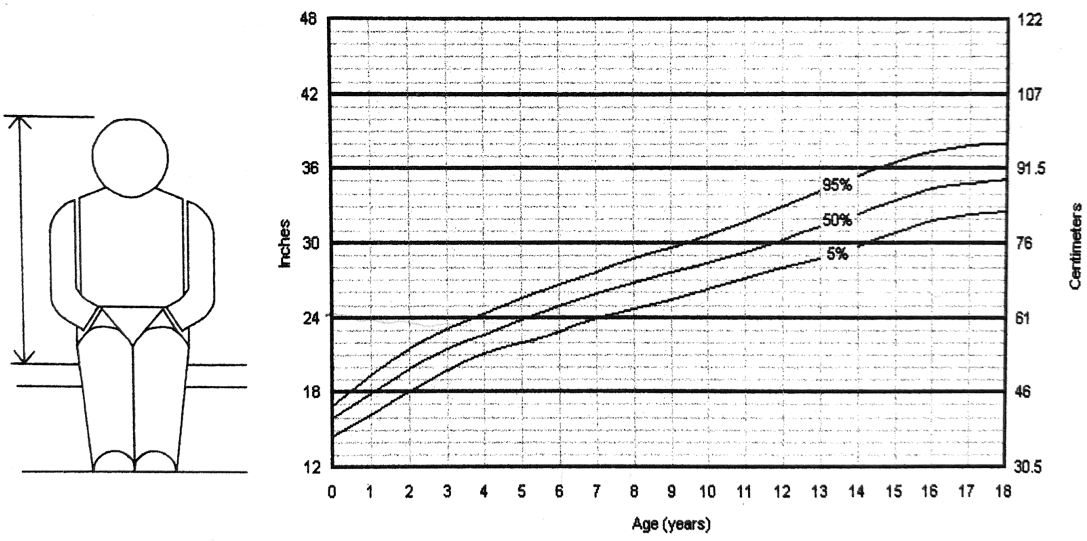


Figure 2.8 Measurement about Seated Height (Ruth, 1999, p. 11)

Shoulder Width

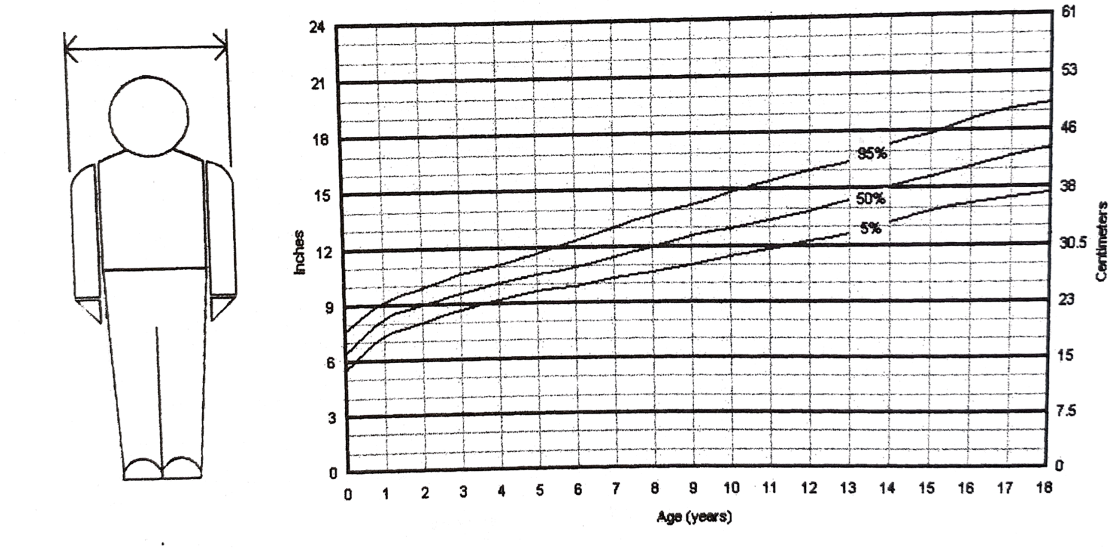


Figure 2.9 Measurement about Shoulder Width (Ruth, 1999, p. 8)

Vertical Reach to Grip

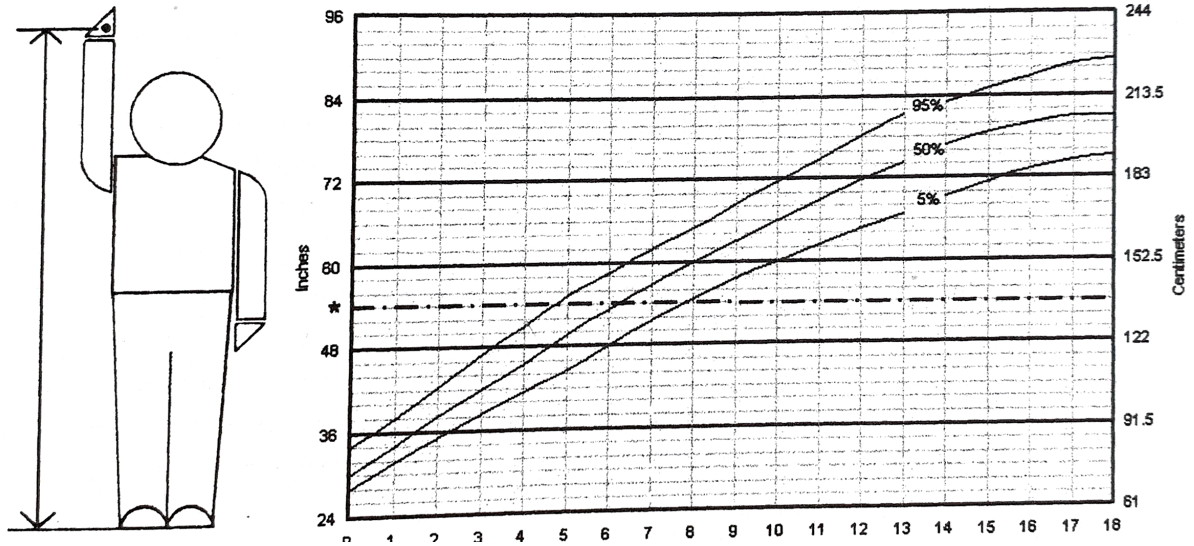


Figure 2.10 Measurement about Vertical Reach to Grip (Ruth, 1999, p. 9)

Span

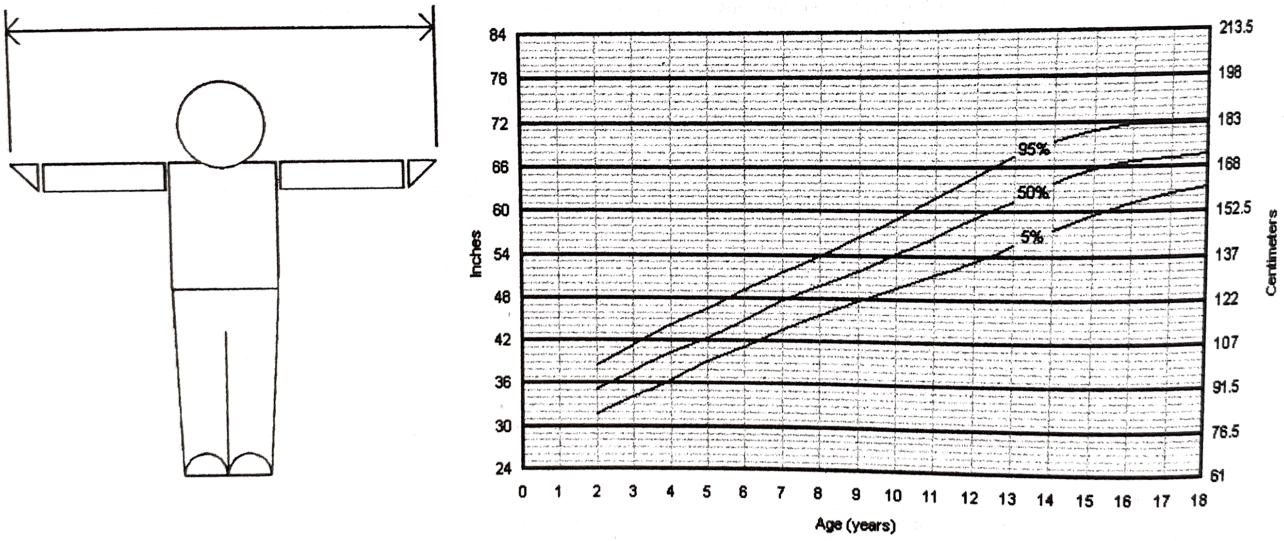


Figure 2.11 Measurement about Span (Ruth, 1999, p. 10)

Seated Eye Level

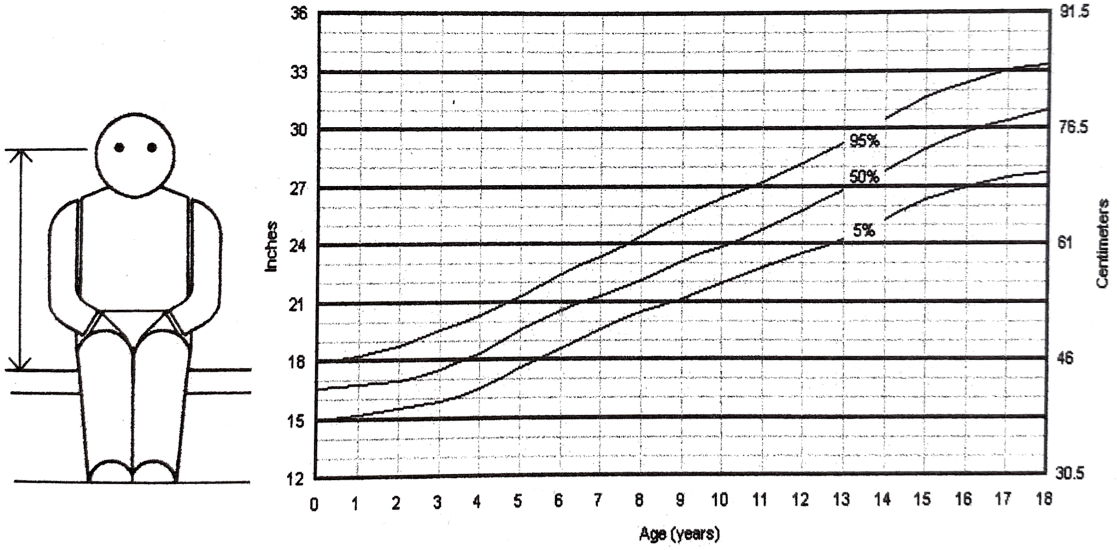


Figure 2.12 Measurement about Seated Eye Level (Ruth, 1999, p. 11)

Standing Eye Level

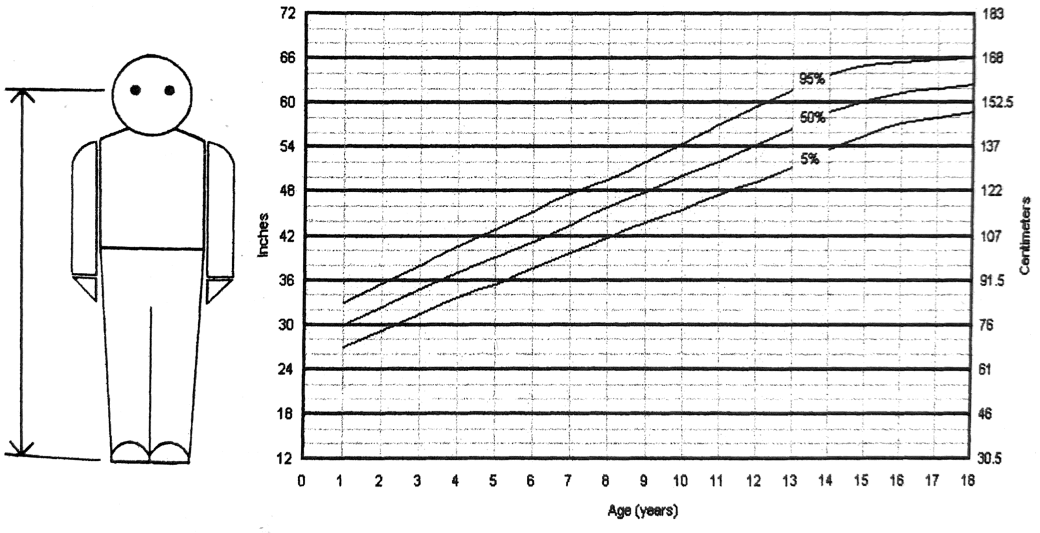


Figure 2.13 Measurement about Standing Eye Level (Ruth, 1999, p. 7)

2.2.2 Motor Development

Newborn Reflex: Newborn babies' motor pattern is more like an automatic response to a particular form of stimulation. That is called a reflex. It includes, but is not limited to eyes blinking, swimming, motor ability, palmar grasp, and stepping. For the eyes blinking, the bright shining light at eyes will stimulate babies to quickly closes their eyelids. For the swimming ability, babies could paddle and kick when they are placed face down in a pool of water. For the motor ability, infants could arch back, extend legs, throw arms outward, and then bring arms in toward the body. For palmar grasp, babies will spontaneously grasp with fingers. For stepping, infants could make a stepping response when caregivers hold them. These abilities will be practiced for babies to prepare for their future motor development. Reflexes will disappear during the first 6 months and switch into the next stage (Berk, 2000).

Sleeping Pattern: For infants, they sleep most of the time in a day. They alternate between REM sleep (rapid-eye-movement sleep) and NREM sleep (non-rapid-eye-movement sleep) just like children and adults. In the first 15 days after born, infants spend almost 8-9 hours on the NREM sleep which is a quiet and regular sleep. They spend 7 to 8 hours on the REM sleep which is an uneven and irregular sleep. The waking hours will only last 8 to 9 hours. When infants grow up, REM sleep will drastically decline over the following years. However, the NREM sleep will change very little (Berk, 2000).

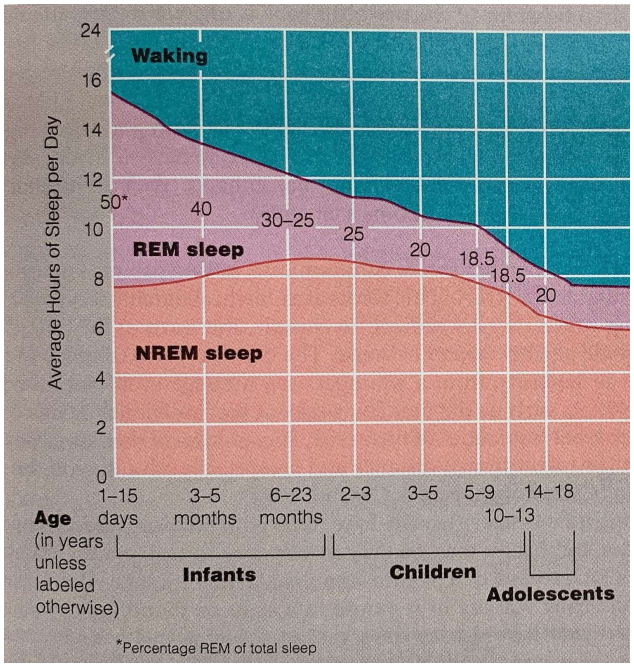


Figure 2.14 Sleeping Pattern from 0 to 20 years old (Berk, 2000, p. 133)

Gross and Fine Motor Skills: When infants and toddlers can do different actions, their perspective on the world will be entirely changed. The development of motor skills also has a powerful effect on their social relationship. The development of Gross Motor Skills helps infants and toddlers to get around in the environment. In contrast, Fine Motor Skills allow them to "do a smaller movement." In different age periods, children will achieve different motor skills. Table 2.1 shows how these motor skills developed in an average age period. The Gross Motor Skills will work in a dynamic system where the separate abilities blend to help infants to produce more effective ways of controlling the environment (Hofsten, 1989). Furthermore, environmental support is vital for babies to develop a new skill (Berk, 2000). Also, what needs to be noticed in

Average Age Achieved	Gross Motor Skills	Fine Motor Skills
2 months	**Rolls** (from side to back)	
3 months, 3 weeks		**Voluntary Reaching** (appears and improves in accuracy, but missed objects) **Ulnar Grasp** (a clumsy motion in which the fingers close against the palm)
4 1/2 months	**Rolls** (from back to side)	**Transfer Object** (from hand to hand)
5 months	**Sits** (with support)	**Reduce Reaching** (when objects beyond their reach)
7 months	**Sits Alone** **Crawls**	**Independent Arms** (reach object by one arm) Bring Objects to Month
8 months		
9 months	**Rolls Over** **Pulls to standing position**	**Reaching Moving Objects** (redirect arm direction) **Pincer Grasp** (well-coordinated manipulation)
11 months	**Stands Alone**	
11 months, 3 weeks	**Walks Alone**	
14 months	**Crawls up stairs** **Hug**	**Scribbles Vigorously**
16 months	**Walks up Stairs with Help**	
18 months	**Runs Stiffly**	**Feeds Self**
23 months	**Jumps in place** **Running** **Walks up Stairs alone** **Walks down Stairs with help**	
25 months	**Walks on tiptoe**	
2 years	**Runs Well** **Climbs on furniture** **Like Fill, Dump, Throw**	
3 years	**Rides Tricycles** **Jump a distance** **Stand on one foot** **Dressing with help**	

Table 2.1 Gross and Fine Motor Skills from 0 to 3 years old (Ruth, 1999; Berk, 2000)

	Motor Development
4 years	Hop on One Foot
	Jump 24-33 in
	Go Down Stairs Alternating Feet with Support
	Throw Balls Overhead
	Climb Well
5 years	Skip
	Running Jump 28-28 in
	Go Down Stairs Alternating Feet without Support
	Dress without Help
6-12 years	Rides Bicycles
	Swim
	Skate

Table 2.2 Gross and Fine Motor Skills from 4 to 12 years old (Ruth, 1999)

Fine Motor Skills is that infants reach objects not by visual guidance but by proprioception, a sense of movement and location in space. (Clifton, Rochat, Robin, & Berthier, 1994)

At the period of three to six years old, children's heads become smaller, and the gravity shifts downward. The most remarkable change in this period is the emergence of upper strength. Children could take advantage of their arms to do the activities that they cannot do before three years old. They will gradually walk more smoothly and get a better balance. They will develop more gross motor skills to use their large muscles and combine their upper and lower body to achieve more complex and effective motor skills (Getchell & Roberton, 1989). Furthermore, when children enter the middle childhood, children have more "improved balance, strength,

agility, and flexibility" in a wide variety of activities (Berk, 2000, p. 177). The main action space will transform from indoor to outdoor. In the adolescent period, boys and girls can reach more achievement in athletic options.The sex-related differences in gross motor development keep increasing and are large at adolescence. The early achievement of some sports will begin in this period.

2.2.3 Perceptual Development

When babies come into this world, they observe their surroundings and take in information from the physical world almost all the time. Babies will significantly develop their perception abilities by combining and absorbing this information. There is one point that needs to be noticed: babies do not develop perceptions separately. On the contrast, they will make all the perceptions together. When one ability develops, the other one will be improved. They are in a system, and they are coordinated with each other (Berk, 2000). In the first six months, the development of perceptual ability will be improved most quickly and importantly. The perceptual system will be established at the end of the first year and mature in the second year.

Touch: In the early ages, infants are pretty sensitive about pain. Soft-care will make babies more comfortable. They will smile and become increasingly attentive (Stack & Muir, 1992). The soft touch from caregivers helps stimulate early physical growth and emotional development. Also, touch is the primary way for babies to investigate their world. They will use touch, tongue, and vision to learn different objects (Berk, 2000).

Smell: The odor preference is innate for babies. They will relate different odors to different emotional expressions. Also, they are quite adept at odor discrimination (Berk, 2000).

Hearing: For newborn babies, they will prefer complex sounds rather than pure tones (Bench, Collyer, Mentz, & Wilson, 1976). At four to six months, babies develop an ability to identify the precise location of a sound and make a judgment about the distance from the sound. Young babies are quickly attentive to high-pitched voices (Aslin, Jusczyk, & Pisoni, 1998). With the proper and precise voice stimulation and relatively quiet environment, babies could strengthen the readiness for language, and the identification of others' feelings through hearing.

Vision: For newborn babies, their vision ability is immature. "Their visual acuity or fitness of discrimination is limited." Also, babies see "equally unclearly across a wide range of distance." Thus, "no visual cues are available" for babies to notice an object (Berk, 2000, p. 154). However, babies are still interested in moving objects. At around three months, infants could better focus on objects. At around two years, babies' vision will reach to the near-adult level (Courage & Adams, 1990). For the color perception, newborn babies show interest in colorful objects, but they do not develop discrimination of colors until the age of two months. At around four months, the color sensitivity is well established.

Depth Perception: Depth Perception is "the ability to judge the distance of objects from one another and ourselves." This ability could help prevent children from "bumping into furniture and falling staircases" (Berk, 2000, p. 156). According to the Visual Cliff study, the researchers concluded that the infants already have the depth perception to distinguish depth and avoid falling. Infants will use different methods to help them detect depth. The first method to develop is Kinetic Depth Cues. It appears at around three to four weeks. Babies will take advantage of body movement to learn about depth. With the motor skills develop, babies'

movement becomes more independent. Thus, their depth of cue sensitivity will be more refined. The second method is Binocular Depth Cues, which mainly rely on the information received by the two eyes. The third method is Pictorial Depth Cues, which will emerge in the middle of the first year. Examples are receding lines, texture changes and overlapping objects (Berk, 2000). The proper and disciplinary illusion could help infants to judge the space depth.

Pattern Perception: Babies' ability of the visual system improves quickly during the first several months. It becomes mature at the end of the first year. Young babies prefer to look at simple, large and patterned stimuli rather than plain stimuli (Fantz, 1961). They also will respond to the separate parts of a pattern (Bronson, 1991). For older babies around two months, they prefer complex, small and patterned stimuli. They also develop the ability to notice the entire border of a geometric shape (Bronson, 1991). At about four months, babies can even recognize the subjective boundaries that do not exist (Ghim, 1990). By the end of the first year, infants can even "extract meaningful patterns on the basis of very little information" (Berk, 2000, p. 161). At the same time, babies' knowledge about their surroundings is expanding. Also, abundant knowledge is the main factor to improve babies' pattern sensitivity (Bertenthal, 1993).

Object Perception: Researchers observed that infants have the innate capacities to distinguish the objects on the actual size and shape, not only on retinal image size or shape. This ability is called Size Constancy and Shape Constancy (Slater, 1997). Also, Piaget (1985) suggested that young infants cannot perceive the boundary between two different sized, shaped or textured objects, and also, they see the two objects as a single unit.

<table>
<tr><th></th><th>Visual</th><th>Pattern Perception</th><th>Object Perception</th><th>Hearing</th></tr>
<tr><td>Birth</td><td rowspan="2">Track Moving Objects</td><td rowspan="2">Large, Bold Patterns
Outskirts of Patterns</td><td rowspan="2">Size and Shape Constancy</td><td rowspan="4">Prefer Complex Sounds
Listen to Music</td></tr>
<tr><td>1 month</td></tr>
<tr><td>2 months</td><td rowspan="2">Perceives Color Across the Entire Spectrum</td><td rowspan="2">Fine Details
Internal Features
Structure</td><td rowspan="2">Use Motion and Spatial Layout to Identify Objects</td></tr>
<tr><td>3 months</td></tr>
<tr><td>4 months</td><td rowspan="2">Organize Colors into Categories</td><td rowspan="2">Subjective Boundaries</td><td rowspan="2">Use Kinetic and Stationary Cues to Identify Objects</td><td rowspan="2">Identify the location of a Sound
Pick up Emotion through voice</td></tr>
<tr><td>5 months</td></tr>
<tr><td>6 months</td><td rowspan="3">Smooth and Efficient Eye Movements</td><td rowspan="3">Extract information</td><td rowspan="6"></td><td rowspan="3"></td></tr>
<tr><td>7 months</td></tr>
<tr><td>8 months</td></tr>
<tr><td>9 months</td><td rowspan="4">Visual Acuity Improve</td><td rowspan="4">Perceive the Meaning</td></tr>
<tr><td>10 months</td></tr>
<tr><td>11 months</td></tr>
<tr><td>12 months</td></tr>
</table>

Table 2.3 Perceptual Development from 0 to 12 months (Berk, 2000)

2.2.4 Social Emotional Development

Emotional Expression and Understanding: At the very beginning at birth, infants begin to express basic facial emotions like happiness, interest, surprise, and fear. In the middle of the first year, emotional expression is well organized and related to social events. Also, infants could express their internal state in multiple and specific ways (Izard, Fantauzzo, Castle, Haynes, Rayias, & Putnam, 1995). At around one to two years old, infants begin to have self-conscious emotions like shame, embarrassment, guilt, envy, and pride. Based on the development of language, they tend to regulate emotions by talking about feeling as their language ability expands (Saarni, Mumme, & Campos, 1998). Empathy also appears in this period which means

infants begin to sense others negative emotions and try to relieve them. In sum, at the very beginning of life, infants hold the essential ability of emotion expression and understanding. The early months are the most critical period for children to form the cornerstone of adult personality and temperament.

After age three, the self-evaluation emerges, which means children's self-consciousness will be enhanced in this period (Lewis, Alescess, & Sullivan, 1992). The early preschool years are vital for children to learn strategies about how to control their feelings. The strategies include but are not limited to emotion display and emotion judging. Children who can have better instruction of emotional practice will get along better with peers when they go to school after six years old (Eisenberg, Fabes, Murphy, Karbon, Smith, & Maszk, 1996). Also, children's understanding of other's emotion improves in accuracy and complexity. They could distinguish the causes, consequences and behavioral signs of different emotions (Berk, 2000). With language maturing, empathy becomes more reflective. Children show the ability to assess another's feelings and rely on words to console others. The children who get better development of empathy will be more sociable, assertive, and good at regulating emotion.

When children go to school at seven or eight years old, the negative emotions that threaten their sense of self-worth will appear. Therefore, the strategies of emotional self-regulation will increase rapidly after school entry. Children tend to find their internal standards for right action. Their internal conformity and conscious awareness of rules improve. Also, in this period, children's expression may not reflect their true feelings (Berk, 2000). Furthermore, on the side of self-understanding, children will begin to mention personality traits in both

positive and negative aspects about themselves. They are less likely to describe themselves in all-or-none ways (Berk, 2000, p. 447).

Contrast to the rapid development on the previous time, adolescent's emotional expression and understanding become mature. They might generate a diverse array of self-regulatory techniques and flexibly adjust them to situational demands (Saarni, 1997). Even though children's emotional expression and gains in empathy mainly develop in early ages, and are influenced by caregivers and family experiences, they still have the opportunity to change the ability of emotional self-regulation.

Self-Understanding: At around three months, researchers observe that the I-self emerges. The I-self is a sense of self as subject, or agent, who is separate from but attends to and acts on objects and other people. For infants, the environment perform a vital role in helping them build an image of self separate from the physical world and the social world (Berk, 2000). At about fifteen months, the me-self emerges. The me-self is a reflective observer who treats the self as an object of knowledge and evaluation. Around age two, self-recognition is well established. The appearance of self-recognition precedes the ability of imitation in play (Asendorpf, Warkentin, & Baudonniere, 1996). Thus, toddlers begin to learn copy behaviors and cooperate with peers to solve simple problems.

Around the age of three-four years old, preschoolers' mind become more differentiated, organized and accurate. They could understand the relationship between beliefs, desires, and actions. Wellman (1990) created the belief-desire theory of mind to explain that both beliefs and desires determine behavior and that closely resembles the everyday psychology of adults. Thus,

it is encouraged for children to do the make-believe play which triggers awareness that beliefs influence behavior (Astington & Jenkins, 1995). Also, the me-self which appear in around fifteen months will expand to a self-concept. As language develops, children in this age period usually mention observable characteristics about themselves and describe themselves in terms of typical emotions and attitudes. Also, their self-esteem is typically high and begins to differentiate at this time.

Furthermore, from the age of six to seven, children's self-esteem becomes hierarchically organized and divided into at least three aspects: academic, physical and social. Contrary to the high self-esteem in early childhood, children's self-esteem declines in this period due to their self-judgment on their abilities, behavior, appearance and other characteristics with other peers (Marsh, Bernes, Cairns, & Tidman, 1984). To shield their self-worth, children will tend to find their achievement goals to raise their self-esteem. In this sensitive period, it is crucial for children to form a mastery-oriented fashion (Attributions that credit success to high ability and failure to insufficient effort). They should be encouraged to pursue a learning goal behave which will highlight a task that will help for their study. In this study mode, children will persist at challenging tasks (Elliott & Dweck, 1988).

The self-concept becomes an organized system of personality traits. Young adolescents usually describe themselves by using contradictory words. This trait comes from "social pressures to display different selves in different relationships" (Berk, 2000, p. 447). Teenagers are struggling to find "which is the real me". Moreover, teenagers show concern about their social virtues, if they are liked or viewed positively by others (Berk, 2000). In the final

development stage, adolescents will "move toward the kind of unity of self that is central to identity development" (Berk, 2000, p. 447). In the process of forming an identity, adolescents usually have four identity statuses, which are identity achievement, moratorium, identity foreclosure, and identity diffusion before constructing a mature identity (Berk, 2000). At the same time, self-esteem continues to rise.

Moral Understanding and Self-Control: From about one to two years old, toddlers begin to notice and be concerned about some acts which have deviations from standards. Also, they will model a wide variety of prosocial acts to try to adopt social norms. The first glimmerings of self-control as the form of compliance appears in this period (Kaler & Kopp, 1990). Opposition also appears at the same time in order for toddlers themselves to assert autonomy. However, the resistance will gradually turn into negotiating compromises during the preschool years.

As preschoolers, children display the reaction of guilt about their transgressions. Also, their internalization of many prosocial standards and prohibitions has occurred. Furthermore, the ability of self-control improves. Children start to learn some strategies from parents. Also, self-control has been transformed into "a flexible capacity for moral self-regulation," an ability that children could monitor and adjust themselves in a changeable circumstance (Bandura, 1991). Children gradually cultivate a delay of gratification which means children will wait for more time to engage in the desired object (Berk, 2000). School-aged children continue to form an internalization of societal norms and expand more strategies of self-control.

Gender Typing: By one to three years old, because of the gender-stereotyped games and toys, children gradually develop a high stereotype about boys and girls (O'Brien & Huston, 1985).

By age five, with the developing of "gender-appropriate" play, gender stereotyping of activities, occupations, and behaviors is well established. Children might have the preference to play with same-sex peers in this period (Berk, 2000). Moreover, gender identity emerges at the beginning of the period, and gender-linked self-evaluation develops at the end of the period.

When children go to school, they have a more extensive variety of gender stereotypes which expands to the areas of personality traits and achievement (Signorella, Bigler, & Liben, 1993). Contrary to early childhood, schoolers' beliefs about gender stereotypes become more flexible. Especially for girls, although their "overall orientation still leans toward the feminine side," their identification with "feminine" declines. In the contrast, boys strengthen their identification with the "masculine" role (Berk, 2000).

When children enter adolescence, the gender-role conformity begins to increase, but then it will decline, especially in girls. Also, girls will become less gender-typed than boys (Huston & Alvarez, 1990).

<table>
<tr><th></th><th>Emotional
Expression</th><th>Emotional
Understanding</th><th>Social
Cognitive</th><th>Moral
Construction</th><th>Self
Control</th><th>Gender
Identity</th></tr>
<tr><td>0-6 months</td><td>Well-organized
Clearly</td><td>Understand Caregiver's
feeling</td><td rowspan="3">Self-recognitive
emerges
Self-evaluation appears</td><td rowspan="2">Concern emerge
Prosocial act begins</td><td rowspan="2">Compliance emerges</td><td rowspan="5">Gender stereotyping
occur
Link to self-evaluation</td></tr>
<tr><td>7-12 months</td><td>Anxiety increase
Self-regulation improves</td><td>Detect other's emotion</td></tr>
<tr><td>1 year</td><td rowspan="2">Self-conscious appears</td><td rowspan="2">Empathy appears</td></tr>
<tr><td>2 years</td><td rowspan="4">Emotion regulating
improves</td><td rowspan="4">Understanding improves
in accuracy and
complexity</td><td rowspan="2">Self-esteem is high
Achievement-related
attributions appear</td><td rowspan="3">Guilt reaction emerges
Prosocial standards
occur</td><td rowspan="3">Self-control emerges</td></tr>
<tr><td>3 years</td></tr>
<tr><td>4 years</td></tr>
<tr><td>5 years</td><td rowspan="3">Self-concept
emphasizes personality
Self-esteem delines</td><td rowspan="4">Gender stereotype
expand
Masculine identity
strengthen</td></tr>
<tr><td>6 years</td><td rowspan="5">Self-conscious relates
with inner standard
Emotion regulating
become internal</td><td rowspan="5">Understand mixed
feelings
Understand expression
may not reflect true
feeling</td><td rowspan="4">continue develop</td><td rowspan="4">Self-control strategies
expand</td></tr>
<tr><td>7 years</td></tr>
<tr><td>8 years</td></tr>
<tr><td>9 years</td></tr>
<tr><td>10 years</td><td rowspan="9">Self-concept becomes
organized
Self-esteem rise
Identity develop</td></tr>
<tr><td>11 years</td></tr>
<tr><td>12 years</td><td rowspan="8">Further improve</td><td rowspan="8">Further improve</td><td rowspan="8">continue develop</td><td rowspan="8">continue develop</td><td rowspan="8">Gender-role conformity
rises and then declines</td></tr>
<tr><td>13 years</td></tr>
<tr><td>14 years</td></tr>
<tr><td>15 years</td></tr>
<tr><td>16 years</td></tr>
<tr><td>17 years</td></tr>
<tr><td>18 years</td></tr>
</table>

Table 2.4 Social Emotional Development from 0 to 18 years old (Berk, 2000)

2.2.5 Cognitive Development

The definition of cognitive development refers to “inner processes and products of the mind that lead to knowing”. (Berk, 2000, p. 221) The process of the psychological activities would contain remembering, symbolizing, categorizing, problem-solving, creating, fantasizing, dreaming, and even more. This section would introduce the theory of children cognitive development from Jean Piaget.

Piaget believes that children would experience four stages of development. They are the sensorimotor stage from birth to two years, the pre-operational stage from two years to seven years, the concrete operational stage from seven years to eleven years, and the formal operational stage from eleven years to older age. During these four stages, the cognition of children would gradually transform from exploratory behaviors to abstract and logical intelligence. Piaget also emphasizes that the environment can affect the speed of cognitive development, which provides the validity of the relationship between childhood development and the adaptable children room design. (Piaget, Inhelder, & Szeminska, 1960)

Piaget conveys an essential idea of the generating process of cognition. He thinks that adaptation and organization can explain how cognitive change happens. The adaptation refers to the mental process that directly interacts with the environment. It concludes the activities of assimilation and accommodation. During the process of adaptation, children can explain the world by their current understanding, and then they can create a new explanation of the world. Moreover, the organization refers to the activities that take place internally. The process would

happen after children form a new understanding. Children would enhance their understanding through this process. (Berk, 2000)

The description of the four stages is summarized on the table below.

	Cognitive Attainments
0-1 month	Exploration limited motor skills Imitation adult gestures
1-4 months	Exploration advanced motor skills Awareness of object performance and solidity Imitation adult facial expression
4-8 months	Exploration improved motor skills Improved understanding of gravity and object collision Use of shape, texture, and color to identify objects Imitation adults behaviors Beginning categorization of objects by function
8-12 months	Intentional and goal-directed behavior Ability to retrieve objects in different location Imitation adults actions Categorization many objects by function Categorization emotional expression
12-18 months	Acting objects in novel way Flexible solution to sensorimotor problems Ability to search location for hidden objects Imitation novel behaviors Grouping objects into a single category
18 months-2years	Ability to find objects that is out of sight Imitation of entire social roles Grouping objects into two categories
2-4 years	Representational activity (drawing, understanding of spatial symbols) Constructs many more categories on the basis of function
4-7 years	Display complex play Create more realistic drawing Depict the third dimension Ability to distinguish appearance from reality
7-11 years	Thinks in a more organized and logical way Shows improved understanding of spatial concepts
11-20 years	Hypothetic deductive and propositional thought Displays the imaginary audience and personal fable

Table 2.5 Cognitive Development from 0 to 18 years old (Berk, 2000)

2.2.6 Research Method Defined

Before the beginning of the discussion of the children development, there are two principles that need to be defined. The first is the the age division. The second is the ability selection.

The age division is related with the continuity of education. Children show different features in different ages. However, in some age levels, the children's development features have similarity and continuity. Depending on the similarity, these age levels would be combined into an age phase. Goals and methods at each age phase are diverse, but cohesive. From birth to adulthood, there will be three main development age phases. The reason and evidence of the age division will be discussed in the following sections.

Children development is a comprehensive science which includes but is not limited to biological, psychological and emotional changes. Also, there are abundant theories from anthropologist, psychologist and educator. With such a wide scope of knowledge, only part of the ability in children's development that could be improved by the design of children's room are selected. The factor of education will not be discussed.

Just like Montessori (1976) said, "We are at the beginning of a long road, along which we will travel with the child. But what we would most like to recommend is not to begin too late" (p. 77). This thesis conveys an approach that the design of a room will also help children to become responsible and contributing adults (Lillard, 1996).

2.2.7.1 Age Division of Children

Before becoming adults, children experience rapid development through different ages. In different age levels, children reveal different or same physical and psychological features. Grouping the age levels according to special development features will provide convenience for this and related future study. Different theories about children development in diverse fields propose different age division methods. The age division present overall age trends; individual differences exist in the precise ages. The division methods will be discussed In the following paragraphs.

Social Emotional Development: According to the social development theory, the development stages are divided into four stages. First is the early childhood stage from birth to three years old. Second is the preschool stage from three to six years old. Third is the middle childhood stage from seven to twelve years old. Forth is the adolescence stage from thirteen to eighteen years old (Berk, 2000).

Motor Development: In the field of motor development theory, children's age levels are divided into four age phases. The first phase is the Reflexive Movement Phase from four months to one year old. The second phase is the Rudimentary Movement Phase from one to two years old. The third phase is the Fundamental Movement Phase from two to seven years old. There are three sub-stages under the third phase which are the Initial Stage from two to three years old, the Elementary Stage from four to five years old, and the Mature Stage from six to seven years old. The forth phase is the Specialized Movement Phase from seven to lifelong. Under the fourth

phase, there also are three sub-stages which are the Transitional Stage from 7 to 10 years old, the Application Stage from 11 to 13 years old, and the Lifelong Utilization Stage from 14 and up.

Cognitive Development: Depending on the theory of cognitive development, the age phases are spilt into four age stages. The first one is the Sensorimotor Stage from birth to the acquisition of language. The second stage is the Pre-operational Stage from two to seven years old. Within the second stage, it can be divided into the Symbolic Function Stage from two to four years old, and the Intuitive Thought Stage from four to seven years old. The third stage is the Concrete Operational Stage from seven to eleven years old. The fourth stage is the Formal Operational Stage from eleven to the age of fifteen to twenty years old.

Psychosocial Development: On the theory of psychosocial development, children's growth before being adults are divided into five main stages. The first one is from zero to two years old. The second one is from two to four years old. The third one is from four to five years old. The forth one is from 5 to 12 years old. The fifth one is from 12 to 19 years old.

Sensitive Period: In Montessori's educational theory, she mainly divided children's development into three planes. The first plane in the children's development is from birth to age six. The second plane is from age 6 to age 12. The third plane is from age 12 to age 18. The time frames mainly depend on Sensitive Periods. The sensitive periods are transitory time periods in which the child appears to be working on one specific area of development to exclusion of all others. It includes different definitive abilities which were over when they were passed (Lillard, 1996, p. 25). Montessori believed that (1996) "we should divide education in planes and each of these should correspond to the phase the developing individual goes through" (p. 25).

The children's development could be predicted to some extent; thus, some changes in the room could also be predicted. So, in conclusion, according to the similar development degree of different development aspects, there will be four main age periods. They are the periods from 0 to 3 years old, 3 to 6 years old, 6 to 12 years old, and 12 to 18 years old. The age division determines the changing times of the children's room. Thus, there will be four significant changes in the children's room corresponding to the four main age stages. However, the need for transformation can occur daily. Often, these will be small changes within the four main significant changes.

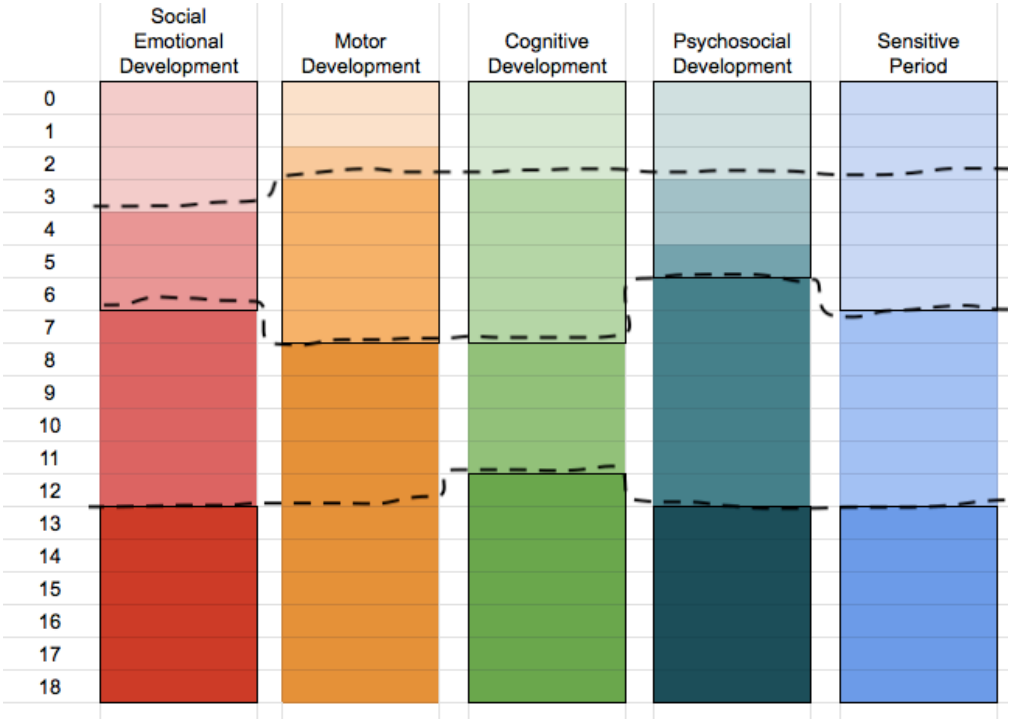


Figure 2.15 Age Division

2.2.7.2 Children Ability Selection

There are two viewpoints about the children ability selection in this thesis that need to be emphasized. The explanation of the two viewpoints can help designers to understand the design approach and design application in the following chapters.

First, the thesis assumed that some abilities can be affected and improved by space. In the contrast, some abilities cannot be affected or improved by the space. Thus, the thesis would be discussed on the abilities which can be affected by the space.

Second, these milestones of features and ability in childhood development represent overall age trends. Thus, the thesis would discuss the mean childhood development situation, whereas some individual differences exist in the precise age at which each milestone is attained. When designers consider precise designs for children, they should take the variation into account.

2.3 Children Residential Space Design

Children's space at home is highly individual. The space should either satisfy children's function needs or their emotional requirements. Children's space should include some essential functions like a sleeping area and storage area. The other functions like the studying area and the playing area are also combined or separated with the sleeping area. Besides the primary functions, color matching, natural lighting control, artificial lighting control, and design safety are also vital for parents and designers to keep in mind. After considering the basic interior elements, it is essential to design the interior background which includes the floor surfaces, the

wall surfaces, and the ceiling surfaces. The color matching, texture choosing, form creation and maintenance are the primary factors that need to be considered about the interior background. Then, the final consideration should be the interior products which include the furniture and the indoor types of equipment. All of the interior elements, background surfaces and products will affect the room adaptability. They should be designed entirely and accurately. The method of children space design will be discussed in detail in the following paragraphs.

2.3.1 Interior Elements

For children space design, there are four primary elements that should be suggested in a macroscopic viewpoint. At first, the choice of primary functions and auxiliary functions would affect the layout of space. Then, the selection of color would determine the entire space atmosphere. Also, the solution of lighting would influence the comfort level for children. Moreover, safety consideration would decide the children's freedom of activity.

2.3.1.1 Function

Primary Area Layout: The layout of activities could present the design of different areas. Also, the function selection, the floor space area, and children's number will determine the layout of the area. Usually, the bed would be the biggest furniture in a room. When needing more functions, more children and less space, designers should consider some space-saving strategies of arrangement. The first strategy is setting folding wood partitions or folding doors to divide one big room into several small spaces. If there is only one child, then the partition could separate the sleeping area from the playing or studying area. If there are two or three children, the partitions will provide them individual sleeping areas. When the partition is closed, children

could have their privacy. When the partition is open, these small privacy places convert into one room which could be a large playing area or studying area. These areas would enhance communication between children. Also, each sleeping quarter could have its own entry. The second strategy is setting the loft as a hideaway above the children's room. Usually, higher space could get more daylight. It could be used as a playing area, studying area or just the storage area. The ladder as the entry into the hideaway could also improve children's gross motor skills. The third strategy of room arrangement is to use built-in furniture. The built-in desk, beds, and storage unit could convert into different functions during the daytime and night time (Hogan, 1970).

Auxiliary Area: The most crucial auxiliary area is the storage area. Also, the storage activity could combine other auxiliary activities to form new furniture. When children grow up, they tend to have large numbers of collections. Thus, they will need plenty of storage space to organize their space fairly. Most of the objects that need to be stored of children will be the toys (hobbies and objects when children get older), books and clothes. There are display and enclosed storage for different objects. Open shelves are usually for toy display. They are easily to reach and quickly return objects to place. The wall hung boxes and cases can also be used as the display function. It is worth mentioning that the storage places for young children could be decorative to make them more fun and attractive (Gilliatt, 1985). Built-in cabinets and closets are often used as enclosed storage. This type of storage will more encourage room neatness. Also, they are more suitable to combine with other functions. The roll-out drawers could be installed under bed and seating. The adjustable shelves could be installed inside the closet. The large bin

or boxes could be set in the living room or kitchen (Hogan, 1970). The installation of the height of storage products should be appropriate for children of different ages to achieve easy reach (Berk, 2000).

2.3.1.2 Color

Color and Emotion: The color's significance in the physical environment to psychology is well established. Children will live more comfortably when they are surrounded by soft colors rather than discordant colors. The researchers found that the background of color in a room has a marked influence on children's behavior. The bright color would bring children a positive manner. Also, it was generally noticed that the cool color would be more soothing and relaxing, and the warm color would be stimulating. Moreover, the color is the essential factor to recognize personality. Everyone will have a preference for color. Also, different colors have their characteristics. Designers need to consider their features when choosing them for decoration (Gilliatt, 1985).

Color Scheme: All color schemes have two main categories: related and contrasting. Related colors produce harmonious schemes. Also, the contrasting schemes will bring a more exciting environment. There are often three ways to create a proper color scheme: monochromatic (one-color plan), analogous (three-to-six-color plan), and complementary (contrasting-color plan).

Other Considerations: The consideration of color cannot be isolated. The relation with its environment should also be taken into account. Both natural and artificial light will influence room color composition. The first consideration of room color scheme would be the quantity and

quality of natural light that enters a room. The room should use light- reflecting colors when there is only a small amount of light. On the contrary, the room should use darker light-absorbing color to reduce glare when there is much amount of light (Allen, 1985).

Color	Emotion
Blue	Cool, Soothing
Green	Serene, Friendly
Red	Conspicuous, Gay, Stimulating
Yellow	Sunlight, Reveraling, Demanding
Gold	Affluence
Pink	Delicate, Subtle, Feminine, Soft, Flattering
Violet	Dramatic
Brown	Warm, Comfortable, Earthy
Gray	Formal
Near-Black and Off-White	Cleaner, Livelier

Table 2.6 Color and Emotion

Artificial light would also affect color and space. Warm light would emphasize the warm color and neutralize the cold color. Also, it will tend to unify objects and bring a friendly atmosphere. By contrast, cold light would intensify cool lights and deaden warm color. Moreover, cold light would expand space and makes space stand out (Allen, 1985). Usually, the color of the ceiling should be the lightest color in a room. The light color makes a feeling of

height about the space, making the space seem larger. When the ceiling is too high, a dark color will make it appear lower.

After discussing so much color usage strategies, the most important thing for designers is to respect children's preference, if the color makes them comfortable or not, regardless of the fashion trend or interior design principles.

2.3.1.3 Lighting

The children's room needs a wide variety of different lightings to meet their different requirements. Also, different types of lightings should be suited to diverse functions in a room. The most common one is the ceiling lamp. It provides a good overall light to shine the whole room. The whole-room-light-up is extremely important for children's nursing and playing. However, as a harsh central light, the ceiling lamp may not be able to emulate the daytime sunlight. Thus, installing even wall lamps would be better to make children live comfortably. They can provide more even shine, and can also fix the light direction to meet children's needs. For young children, wall lamps can also be decorated to attract their attention. Another necessary type of light is the night lamp. It enables parents to read bedtime stories for young children and enables children to read books before sleeping. Some children may be afraid of the dark. The luminous plug or dim lighting would make them feel safer and comfortable at night. Moreover, when children get older, they would more require the work lamp or the table lamp for their workplace (Gilliatt, 1985). Especially for school children who will spend much time on their study, choosing a low-hanging lamp, an adjustable angle-lamp, a flexible clamp lamp or a swivel desk lamp would be the best solution for them. At the same time, parents and designers must

consider the safety of the lamps. For example, a family would better to avoid any free-standing lamp for toddlers. They will easily pull them over and play on the surface.

2.3.1.4 Safety

To better design a children's room, it is vital to consider the possible general hazards. According to the analysis of children's paint points at home. There are several strategies that designers should keep in mind. First, children should be careful of all the sharp corners. Usually, rounding these corners by using corner bumpers would help. Also, all edges should be rolled or have rounded capping. Second, children should avoid contacting sharp protrusions and projections. Third, the width of any fencings on any furniture or ladders should also be noticed. Young children might fall off from the entrapment. The space between all fencings should be more than 3.5 inches (8.9 cm) or less than 9 inches (23 cm) (Ruth, 1999). Fourth, any flexible elements like cables, wires, ropes should also be carefully arranged. They cannot be located in any circulation area or traffic area. The bright color on them will add visibility. Fifth, designers should be aware of the area of the use zone of different function. Sixth, the outlets should be out of reach of toddlers (Gilliatt, 1985).

2.3.2 Interior Background

The interior background includes floor surface, wall surface, and the ceiling, which usually establishes the general scheme of a room. A good design of background would bring an atmosphere of harmony and unity. Not like the movable objects, the background design will be stationary and hard to overhaul in the future. Therefore, it is essential for homeowners to carefully and seriously consider the design of the background.

2.3.2.1 Floor and Flooring Covering

Children usually would like to gravitate to the floor regardless of other seating or furniture. Especially in early years, there should be as much open space as possible, so that young children could lie on it, sit on it and crawl on it.

Some features that are crucial to include the proper flooring material. The material should be warm to touch, which makes children comfortable. Also, the surface should have no projections. A flat surface is ideal for children to play on. For parents, the material should be easy to clean and maintain. According to different functions, the selection of soft material could reduce injury when young children fall from high furniture. The sound-proof material could efficiently cut down the noise. Then whether the surface is bright and good looking also need to be taken into consideration.

There are some excellent choices about the hard surface for children's room. The vinyl-coated cork tiles, vinyl tiles, sheet vinyl, cushioned vinyl, linoleum, polyurethaned wood, and rubber stud are always recommended. Also, there are some options for soft surfaces. The carpet, smooth-finish carpet, and wool cord carpet are good noise-absorbing material. They are also smooth enough for children to pull their toys. Moreover, the arrangement of hard surface and soft surface (some areas of the carpeted platform) would depend on the children's need and the different function of use area. Furthermore, it should be noticed that when children get older, the floor material should be changed with their various need.

2.3.2.2 Wall and Wall Treatments

As the largest usable area in space, walls are both functional and aesthetic. As for the function, walls provide people the separation from the outside environment. Similarly, they also offer designers an opportunity to decorate the space. Moreover, they can be changed to enlarge or narrow the space. This section would discuss the solution of the walls that used inside a room. The solution includes rigid wall materials and flexible wall coverings.

Rigid Material	Characteristics
Plaster and Stucco	Smooth and Textured. No seams or Joints.
Brick	Durable. Warmth. A variety of sizes, shapes, and colors.
Stone	Durable. Solid. A variety of colors and textures.
Cement	Sustantial. Cold. Generally bold.
Ceramic Tile	Aesthetic Quality. Easy to maintain. A variety of colors, shapes, and patterns.
Glass Block	Translucent. Permits light into dark areas.
Solid Wood	Natural grain and color. Can be stained any color. Expensive. A little upkeep.
Plywood	Inexpensive. Easy installation.
Fiber Glass Panels	Translucent. Available in flat sheets and in several thicknesses.

Table 2.7 Rigid Wall Materials (Allen, 1985, p. 179)

Flexible Material	Characteristics
Vinyl-protected Wallpaper	A coating of vinyl plastic. Washable.
Vinyl Latex Paper	Durable. Scrubbable.
Coated Fabric	Durable. Tough. Scrubbable.
Plastic Foam	Soft. Flexible. Absorb sound and insulates.

Table 2.8 Flexible Wall Coverings (Allen, 1985, p. 184)

2.3.2.3 Ceiling

The ceiling is the largest unused area in a room., but the treatment of the ceiling is natural to be ignored. The ceiling also plays an essential role in the atmosphere of a room. The different height, type, and size of the ceiling deserve a different treatment. The ceiling that higher than eight feet can bring people a feeling of dignity and formality. In the contrast, the ceiling that lower than eight feet can create a cozy and private atmosphere of the space. Then, the darkness and the texture of the ceiling can achieve diverse feelings of the space. Usually, a dark and patterned ceiling can be seemed lower than it initially would be. This section summarized some types of ceiling materials.

Ceiling Material	Characteristics
Plaster	The surface may be plain or textured.
Acoustical Tile	A variety of colors and patterns. Easy to install. Washable.
Acoustical Plaster	Attractive. Rough textured surface. Absorb noise.
Wood	Seldom used for entire ceiling. Wooden beams. Plain or painted.

Table 2.9 Ceiling Material (Allen, 1985, p. 193)

2.4 Conclusion

As the thesis discussed before, the living environment can play an essential role in the development of children. The living space can even shape the psychological and physiological features of children. A proper space would contribute to the studying ability, motor ability, and social ability of a child. In the contrast, a poor environment would produce a negative impact on children. They may show poor academic performance or disturbing emotion when they grow old. There are milestones of childhood development. Once they miss the developed sensitive period, they may never acquire some abilities.

Based on this consideration, the adaptability of children room design deserves to be discussed. Before children enter school, they may spend a quarter of time staying at home. The quality of the room design inside the house would directly impact childhood development psychologically and physiologically. Thus, designers need to devote more energy to consider the

children room design, which can stimulate children's potential and makeup with their deficiency. With children's growth of age, they may need more independent space. Also, they would spend less time at home than in the previous age periods. However, the impact of the living space is not reduced. Hence, in order to meet new demands and adapt various needs, the children's room should provide corresponding functions instantly. Chapter Three would offer a proper design approach for designers to produce a children's room with adaptability.

Chapter 3 Design Approach

The following design approach will provide designers a way to create an adaptable children residential room design step by step. It will apply the necessary knowledge about children's room design, childhood development, and adaptable housing design, in order that the room would be more flexible to fit a child's needs in different age periods. Also, the forward-looking design would help parents to spend less time and lower cost to achieve the goal.

The interior design of the residential children's room can be split into three steps: Preparing Phase, Concept Design Phase, and Implementation Phase. The first step will be the Preparing Phase. The initial step is to research the essential elements in the room, which will include Space Fundamental Elements Research and Customer Research. The completeness of this research will influence the concept design. The second step will be the Concept Design Phase, which contains the Analysis, Concept Design, and Final Delivery. In this phase, designers will explore different concepts and strategies based on the research. The selected strategies will be evaluated. Also, the designers would determine how space will be adapted in the future. The final step would be the Implementation Phase. This phase will discuss the application of design strategies.

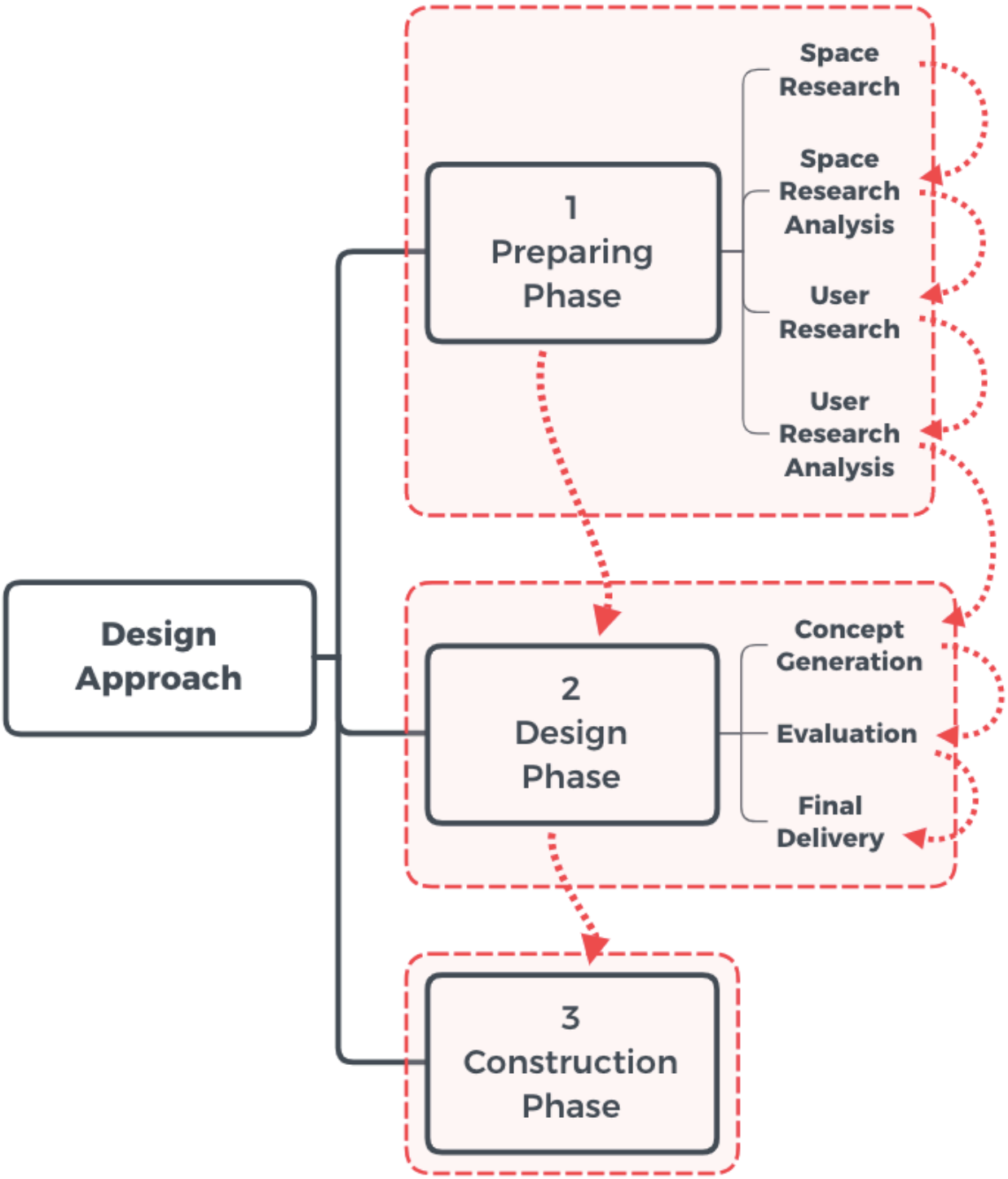


Figure 3.1 Design Approach

3.1 Preparing Phase

The first step of the approach is the Preparing Phase. In this phase, designers need to collect as much information as possible about the room and the user. Then, they need provide analysis of the research. According to the measurements, designers need to fill the tables about space research and user research. The tables will be presented in the following paragraphs.

3.1.1 Space Research

Interior Space Research: The Interior Space Research includes the research of House Type, Room Size Information, and Room Dynamic Information. The House Type and the Room Size Information determines the foundation of the design. Different features of a room would provide different limitations and potentials. Designers need to find as comprehensive information as possible to make sure that they uncover the full potential of a room.

The house type will also influence the limitation of the overhaul. Generally, the overhaul of the house would have more opportunities than of an apartment. More opportunities mean that more walls could be removed or relocated; thus more space could be created. The roof type will also affect the creation of vertical space. A house with a pitched roof may offer more options for designers. Designers could check the box about house type in the research table.

Room Size Information is also essential for designers to pay attention to. It includes the total area of a room. The area of a room will allow or limit the future division of the space. The larger of the area, the more units could be created from a space. Also, designers need to measure the length, width, and height of a room. A room with large proportions will commonly be more prone to adaptability. Usually, a home with square proportions will also permit a more excellent choice of interior configuration (Avi, 2002). Generally, the minimum suitable width of a room

will be 2.8 meters (9 feet). When designers divide a room into several small spaces, they should always leave a suitable width for space.

Moreover, except for the typology and shape of a room, the door and windows are also the vital factors that designers need to observe and measure carefully. The location, scale, and quantity of doors and windows in a room need to be recorded in detail and filled into the research table. The location of a door will affect the subsequent space division and the way of entry. When an entry door is located in the middle of the front facade, the interior space will naturally be divided into two areas with circulation in between. So, this location of the door will limit future adaptability (Avi, 2002). On the contrary, when an entry door is located aside of the facade, the room will have more options for the division. Also, when designers create a new independent space, they should also carefully consider the access to space. To summarize, designers need to sketch the plan, elevation, and the isometric view of a room to directly present the information.

Furthermore, designers need to record Room Dynamic Information, which includes natural light research and circulation research. The site of the residence and the window glass transparency will affect the strength, time, and area of the natural light. The natural light changes seasonally. To better evaluate the sun exposure, designers should sketch the light area in the room for each of the four seasons. Also, designers should depict how the natural light looks in the room in the morning, at noon and at dusk in every season. This sketching will come together into a variation map of natural light. To better provide children a suitable light environment, designers may balance the natural light, the artificial light, the color, and the texture of a room. Besides the research of natural light, the research of ventilation and internal circulation are also

necessary to take into account. They will affect furniture placement and space configuration. Designers might sketch down the plan of what they recognize.

Interior Space Research

House Type	Room Size Information		
☐ Apartment / ☐ House ☐ Flat Roof / ☐ Pitched Roof	Area: _____ Length: _____ Width: _____ Height: _____	Door Location: _____ Door Scale: _____ Door Quantity: _____	Window Location: _____ Window Scale: _____ Window Quantity: _____
PLAN		ELEVATION	
ISOMETRIC VIEW			
1			

Table 3.1 Interior Space Research 1

Interior Space Research

Natural Light		
Site: _____		Glass Transparency: _____
Spring	PLAN	
Summer	PLAN	
Autumn	PLAN	
Winter	PLAN	
Ventilation and Circulation		
PLAN		
2		

Table 3.2 Interior Space Research 2

Exterior Space Research: The Exterior Space Research includes the research of House Construction, Outside Environment, and Noise Assessment. Compared to the interior space. Exterior space may have less effect on indoor conditions. However, exterior spaces cannot be ignored. The outside atmosphere can also allow or limit the consideration of the design inside the room. Designers need to take all factors into thorough consideration. The careful and thoughtful consideration can bring more potential in further analysis and design.

The first step of recording the exterior situation is to write down the type of house construction. Designers should examine whether the residence is built from timber frame, wood panels, manufacturing, concrete, steel stud, or others. Different residence structural envelopes will determine the limitation of the overhaul, refurbishment, and decoration of a room.

The second step of exterior environment research is to observe and record the outside natural circumstances. It contains the research of virescence, roads, and neighborhood distance. The distance, quantity, and types of virescence will affect the lighting and ventilation. Proper quantity of tree shade would reduce the direct hard sunlight, so designers might not need to use other methods to avoid hard sunlight. Also, the lack of virescence might cause children's sad feelings. Thus, designers should pay more attention to the emotional atmosphere of a space. Then, the distance between roads and residence, and the types of roads will affect the social environment for children. Near distance would bring more social opportunities. After that, designers should also consider the existing neighborhood. Public or private outside circumstances bring children different safety and emotional stability. Designers should create a different interior space to balance children's feelings.

The third step of exterior research is the noise assessment. Designers need to consider the comprehensive noise resources and present the solutions.

Exterior Space Research

House Construction	Timber Frame / Wood Panels / Manufacturing / Concrete / Steel Stud / Others	
Outside Environment	Virescence	Distance: _____
		Quantity: _____
		Type: _____
	Roads	Distance: _____
		Type: _____
	Neighborhood Distance	Distance: _____
		Type: _____
Noise Assessment	Cars / People / Animals / Others	
3		

Table 3.3 Exterior Space Research

3.1.2 Space Research Analysis

Designers need to examine space research results. As the thesis detailed before, designers could get the data on both interior space and exterior space. They will know the construction and type of the room; the area, width, length, and height of the space, the location, scale and quantity of doors and windows; the natural light and ventilation; the virescence, roads, and existing neighborhood. According to this data, designers could analyze the potential utility of the space from the following several aspects: space function, space configuration, space expansion, access, circulation, pre-manufactured components, furniture, play equipment, and surface finishing.

Taking the door location as an example, if designers know that the door is located near to a side wall rather than in the center according to the investigation, designers could conclude that it will leave the space uninterrupted by circulation and leaves vast expanses of wall area for furniture arrangement. Thus, under this room condition, the space variation would be more flexible. Also, if the designers notice the window is large in the room, they could decide that space would have greater exposure and more sunlight. Designers also need to make a careful assessment of these openings to see if the room temperature will be too high in summer or too cold in the winter. The design strategy for increasing energy efficiency should be considered. Similarly, when the children grow up and leave home, based on the consideration of function, designers could combine children's room with other public functions if the dwelling type permits.

With the literature review as a reference, designers should write down everything that they think is important from their deduction of the room. Sketches are also vital in this step. Designers could use sketches to represent their thinking about the potentials and limitations of

the space. They will be helpful for the concept design. The analysis is a necessary step in the design phase. It would help designers better understand the space and provide support for the next step.

3.1.3 User Research

User Research One: On the form of user research one, designers would examine the necessary information about children. It would include the name, age, and gender of the children. Then, parents need to select the age periods of the children room. Finally, they need to write down the living habit and interest of the children, and also the style preference of the space.

This section will discuss the reason why designers will choose an age range for children, and the method of how to do it. As Chapter Two represented, variations in childhood development happen every day. To make a room adaptable, designers need to make some changes to the room design. However, it is unpractical to overhaul the children's room every day. Thus, it is essential to set a standard about the frequency of the room refurbishment. The stages of childhood development can be the standard.

Based on the analysis of different phases of childhood development, children's growth time is divided into four primary groups between birth to eighteen years old. At the turning points of three years old, six years old, twelve years old, and eighteen years old, most of the children would have different behavior and demands than before. Hence, the age division groups are split from birth to three years old, from three to six years old, from six to twelve years old, and from twelve to eighteen years old. Each child has a different development pace. Therefore, the age division is just a general standard. This age division will be used as a reference for designers to arrange when it is required to renew the children's place.

As Table 3.4 shows, there are six age range options which correspond to various starting ages and ending ages with which parents would like their children's room accommodated. Designers propose this table, and parents could make their choice. Also, there are six space adaptability times, which means the time to make a significant change to the children's room. Then, parents need to write down their wants about small changes within the period of a significant change. Designers would adjust the design strategy according to the parents' and child's interests.

Moreover, the research would suggest that parents and children communicate more details about their living habits and interests with designers. The survey would help designers to get more precise information from the users, which would assist designers to decide on the design. It might happen that parents can not offer any practical information if the children are not born. Under this situation, designers can inspire parents to write down their expectation for their kids.

Furthermore, in the section of style preference, parents need to clearly express their personal preference about space aesthetics and design style. Do they want a room with modern style design, rustic style design, classic style design, Japanese style design, Nordic style design, or even design without any style. It might be different in various countries, culture, and religion. Also, it might vary according to diverse individual interests. Thus, designers should adjust their design method to different conditions. This thesis will not discuss at length design style. However, it is still a necessary step for designers to implement the design approach.

User Research Two: Except for getting the basic information, designers need to get further information about the demands of childhood development. The table of use research two

User Research 1

Name: _____ Age: _____ Gender: _____		
Children Age Selection		
Selection	Beginning Age Period	Ending Age Period
☐	Age 0-3	Age 3/6
☐	Age 0-3	Age 6/12
☐	Age 0-3	Age 12/18
☐	Age 3/6	Age 6/12
☐	Age 3/6	Age 12/18
☐	Age 6/12	Age 12/18
Living Habit	Interest	Style Preference
1		

Table 3.4 User Research 1

affords a chance for designers to learn more about children's needs. This table also closely related to the Concept Generation. The amount of the second table would be provided corresponding to the age periods.

First, researchers need to fill in the name and gender of the children. Then, they are required to examine the physical features of kids. The data should be collected by the real measurement if it is possible. Alternatively, designers should use the mean height and weight that accord with the national reference values, which is shown in Chapter Two. The data can assist designers to create the prefabricated system and select furniture for kids.

Second, parents need to fill in the function zones and pain points. The main functional zones in the children's room will include a sleeping area, a studying area, and a playing area. However, the studying area or the playing area often will be separated from the children's room to an independent single room. Also, if the children's room has enough area, there will be other more auxiliary functional zones, like a hobby room or a mud room. For example, children probably would like fewer functions at early ages, and be eager to have more functions at middle childhood. The prediction of functions can help designers to make a better decision of room refurbishment. As for the pain points, parents are required to write down their concerns of childhood development.

Finally, parents need to read each option of the childhood development form carefully. They can check the abilities or needs that they would like their children to cultivate. They can check all of the options or check none of them.

User Research 2_Age 0-3

Basic Information	**Name:** _____ **Gender:** _____	
Physical Features (cm, kg)	**Height:** _____ **Weight:** _____ **Shoulder:** _____ **Arms Span:** _____ **Vertical Reach to Grip:** _____ **Seated Eye Level:** _____ **Standing Eye Level:** _____	
Function	_____	
Pain Points	_____	
	Ability / Need	**Analysis**
Motor Development	**Roll / Sit / Crawl** ☐	
	Stand / Walk ☐	
	Walk up / down stairs ☐	
	Run ☐	
	Climb ☐	
	Jump ☐	
	Throw ☐	
	Ride ☐	
Perceptual Development	**Touch Stimulation** ☐	
	Hearing Stimulation ☐	
	Vision Stimulation ☐	
Social Emotional Development	**Self-emotional expression** ☐	
	Self-conscious expression ☐	
	Self-evaluation regulation ☐	
Cognitive Development	**Imitation of behaviors** ☐	
	Understanding of objects ☐	
	Awareness of categorization ☐	
2		

Table 3.5 User Research 2.1

User Research 2_Age 3-6

Basic Information	**Name: _____ Gender: _____**	
Physical Features (cm, kg)	**Height: _____ Weight: _____ Shoulder: _____** **Arms Span: _____ Vertical Reach to Grip: _____** **Seated Eye Level: _____ Standing Eye Level: _____**	
Function	_____	
Pain Points	_____	
	Ability / Need	**Analysis**
Motor Development	**Walk up / down stairs** ☐	
	Climb ☐	
	Jump ☐	
	Throw ☐	
	Dress ☐	
Social Emotional Development	**Self-emotional regulation** ☐	
	Self-conscious expression ☐	
	Self-esteem establishment ☐	
	Self-control establishment ☐	
Cognitive Development	**Drawing** ☐	
	Understanding of space ☐	
	Complex play ☐	
	Distinguish reality & illusion ☐	
3		

Table 3.6 User Research 2.2

User Research 2_Age 6-12

Basic Information	**Name:** _____ **Gender:** _____	
Physical Features (cm, kg)	**Height:** _____ **Weight:** _____ **Shoulder:** _____ **Arms Span:** _____ **Vertical Reach to Grip:** _____ **Seated Eye Level:** _____ **Standing Eye Level:** _____	
Function	_____	
Pain Points	_____	
	Ability / Need	**Analysis**
Motor Development	**None**	
Social Emotional Development	**Self-emotional regulation** ☐	
	Personality expression ☐	
	Self-esteem improvement ☐	
	Self-control improvement ☐	
Cognitive Development	**Thinking logically** ☐	
	Understanding of space ☐	
4		

Table 3.7 User Research 2.3

User Research 2_Age 12-18

Basic Information	**Name:** _____ **Gender:** _____	
Physical Features (cm, kg)	**Height:** _____ **Weight:** _____ **Shoulder:** _____ **Arms Span:** _____ **Vertical Reach to Grip:** _____ **Seated Eye Level:** _____ **Standing Eye Level:** _____	
Function	_____	
Pain Points	_____	
	Ability / Need	**Analysis**
Motor Development	**None**	
Social Emotional Development	**Personality expression** ☐	
	Self-esteem improvement ☐	
	Self-control improvement ☐	
Cognitive Development	**Propositional thought** ☐	
	Display imaginary audience ☐	
5		

Table 3.8 User Research 2.4

3.1.4 User Research Analysis

According to the user research, designers would know the life span of the room, the space adaptability times, the function, design style, and prospective cost, when the parents choose the age division options from the beginning age period age zero to three to the ending age period from age twelve to eighteen. The room have the longest life span, which would bring the most intricate design condition. Designers have to consider four interior design concepts

corresponding to the period of zero to three, three to six, six to twelve, and twelve to eighteen. Moreover, designers need to consider three adaptability methods for the age period transition.

Then, designers should consider the user's personal interest in their room design. It may refer to cultural variation, style preference, and religion influences. These factors may affect the selection of color, material, decoration, and furniture. Afterward, according to the project cost that the user provided, designers should give proper advice on room design. Normally, the cost contains the budget of concept design, the budget of labor fee, and the budget of material, furniture, and equipment selection.

Finally, designers can write down their thinking, concepts, and advice on the form of user research two. There is a blank space on the bottom right of the form where designers can write down all their plans.

3.2 Design Phase

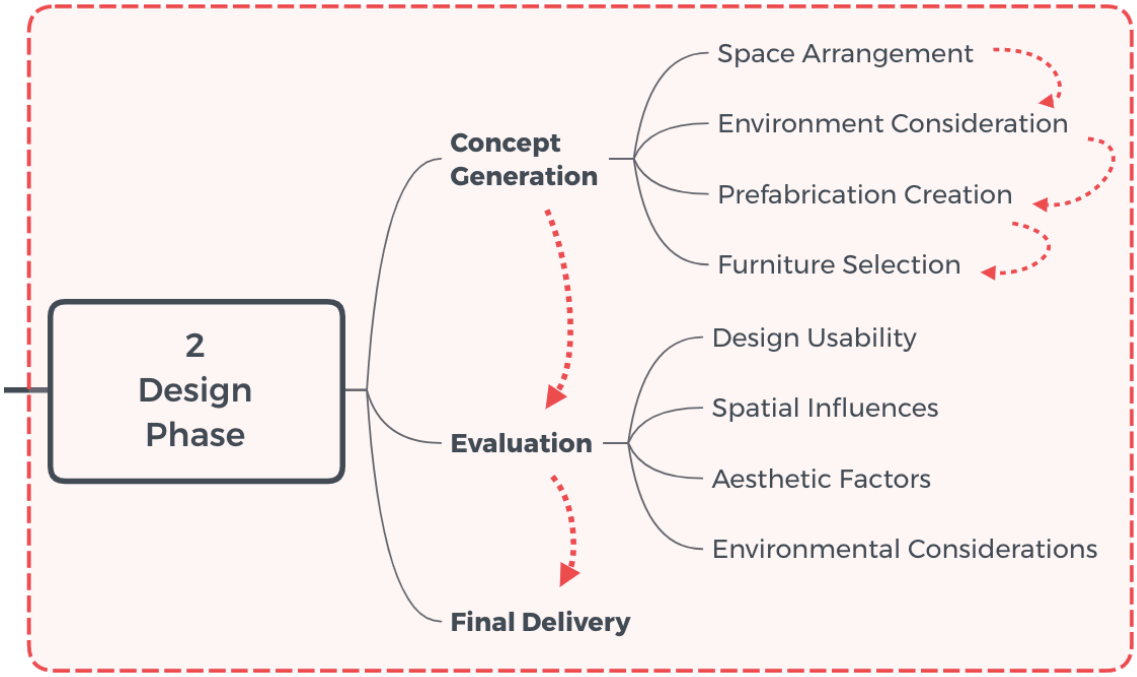


Figure 3.2 Design Phase

The Design Phase is the second step in the Design Approach. After the Research Phase, designers have already mastered the essential information on children's room and requirements. Thus, designers can take advantage of the outcomes of investigation to begin to design the whole children's room. In the Design Phase, designers can be required to achieve three processes which are comprised of the Concept Generation, Evaluation, and Final Delivery. The thesis addresses how to complete the three process in details in the subsequent sections.

In the section of the Concept Generation, designers should understand either the process of the concept design method or the specific methods of each process. The process of concept design is Space Arrangement, Environment Consideration, Prefabrication Creation, and Furniture Selection. Each of the process will be discussed in details in the subsequent sections.

Then, in the section of the evaluation, designers need to evaluate the space design from different indexes. On the process of evaluation, there are four first class indexes, 17 second class indexes, and 43 third class indexes. Designers need to give weights to the first class indexes and second class indexes. Then, they need to give both weights and scores to the third class indexes.

At the final step, in the section of the Final Delivery, designers need to know what kind of final representation will be expected. This thesis would advise some forms of final representation that could clearly show the design and adaptability of the children's room. Also, designers will be required to finish necessary construction documents and provide final cost for the users.

3.2.1 Concept Generation

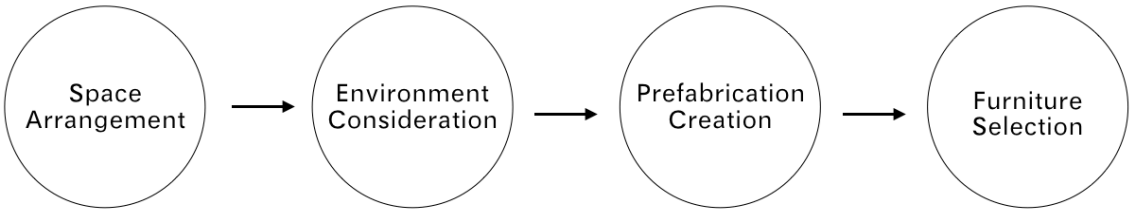


Figure 3.3 Concept Generation

As the first step of the design phase, the concept generation contains Space Arrangement, Environment Consideration, Prefabrication Creation, and Furniture Selection. Designers are required to follow the order of these sections to finish the design of a growing children space. The Space Arrangement and Environment Consideration would be regarded from the macroscopical perspective. After completing the first two sections, the Prefabrication Creation will allow designers to solve specific issues and achieve distinct demands of childhood

development. Finally, the thesis would suggest designers to assist parents and children to select proper furniture and present the final appearance of the room design.

3.2.1.1 Space Arrangement

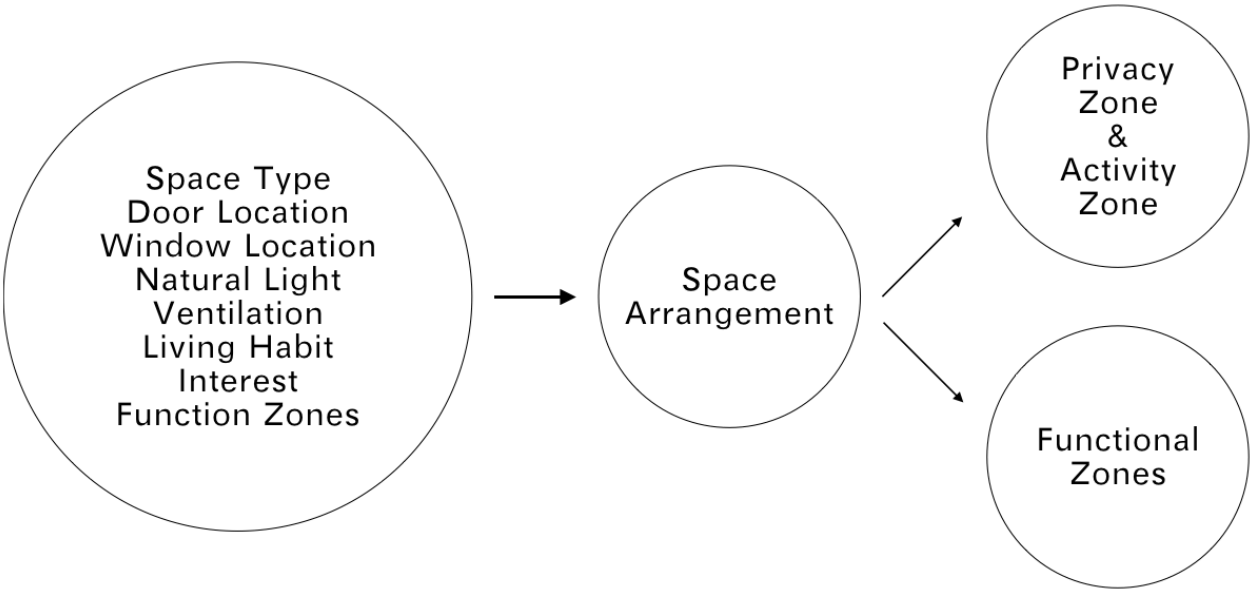


Figure 3.4 Space Arrangement

Influence Factors: Several factors can impact the reflection of space arrangement. These factors might include the space type, door location, window location, natural light, ventilation, children living habit, children interest, and the expected function zones. The door and window location might decide the noise effect on the different parts of the room. Also, because of the diverse preference of users, some activities might need more natural light and fresh air, some might not. Designers need to look through space and user research thoroughly to make the accurate determination of space arrangement.

Privacy Zone and Activity Zone: As the beginning of space arrangement, designers need to consider to divide the area by sound. Usually, space can be separated into the privacy zone and activity zone. The proper distribution of the two distinct zones can suppress and reduce interference within different daily activities. On some extent, it can also save cost and limited space. The correct detachment of the areas can provide a beneficial base for the future distribution of functional zones.

The privacy zone mainly includes the sleeping area, and it can also include the reading area, studying area, and storage area. Similarly, the play area, social area, hobby area, and workout area can be contained in the activity zones. Designers need to think of user's demands and future division when they project the initial space division.

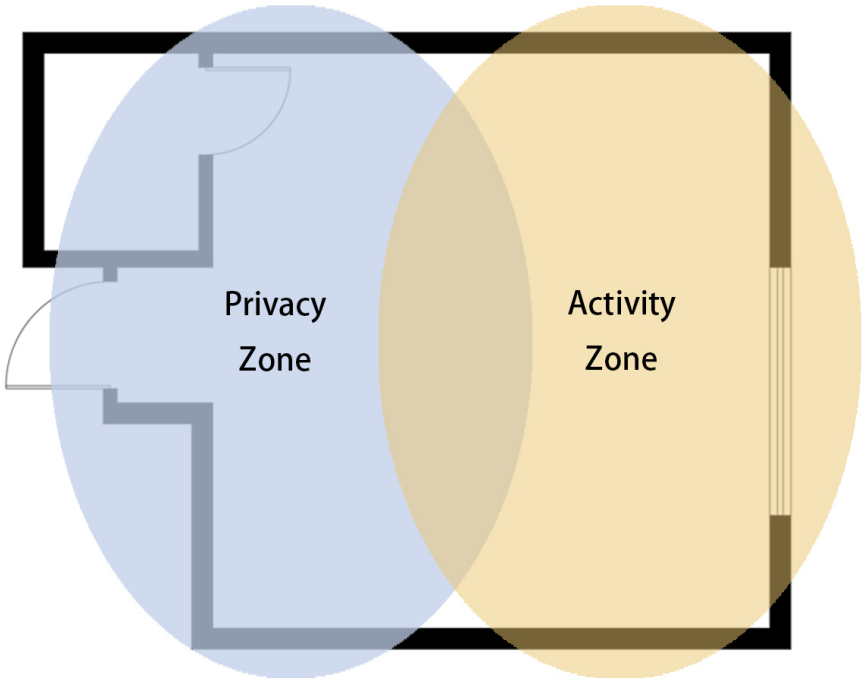


Figure 3.5 Privacy Zone and Activity Zone

Functional Zone: Based on the scientific and reasonable privacy and activity zones division, designers need to consider the functional zones in this step. Some functional zones should be only in the privacy zone or activity zone. In the contrast, some functional zones can be changed between the two distinct zones. Designers should not only deliberate the functional zones in one age period but also the adaptability of these functional zones. Different functional zones can be interpenetrated, transformed, or isolated with each other. Designers should also think of the multifunctions of different zones.

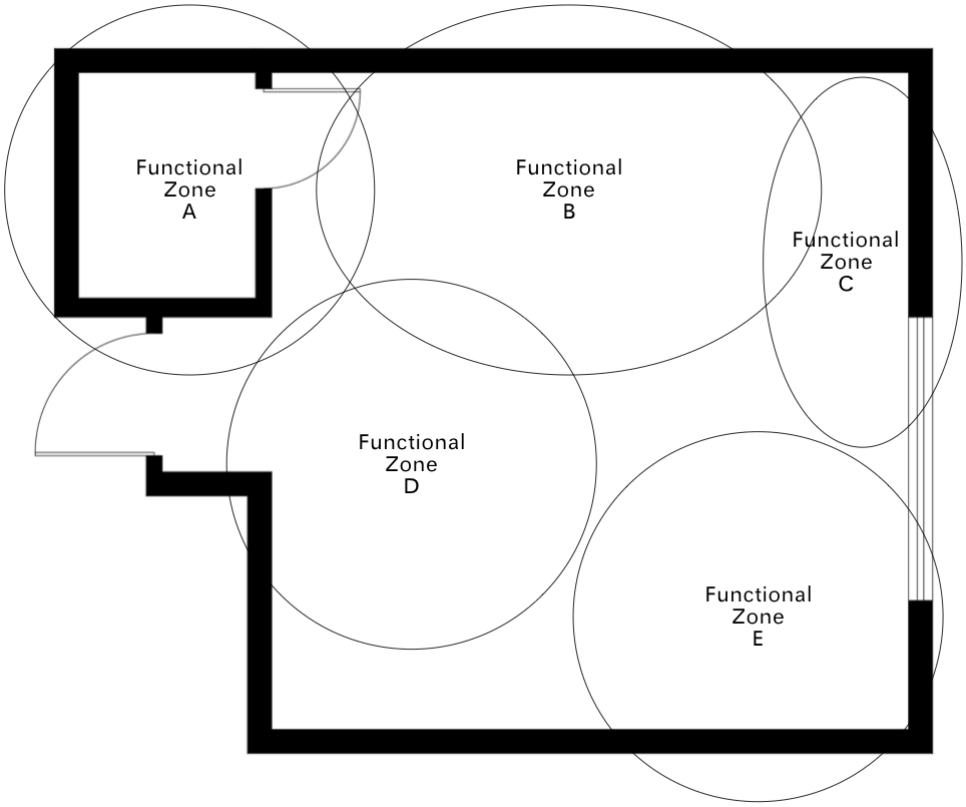


Figure 3.6 Functional Zones

3.2.1.2 Environment Consideration

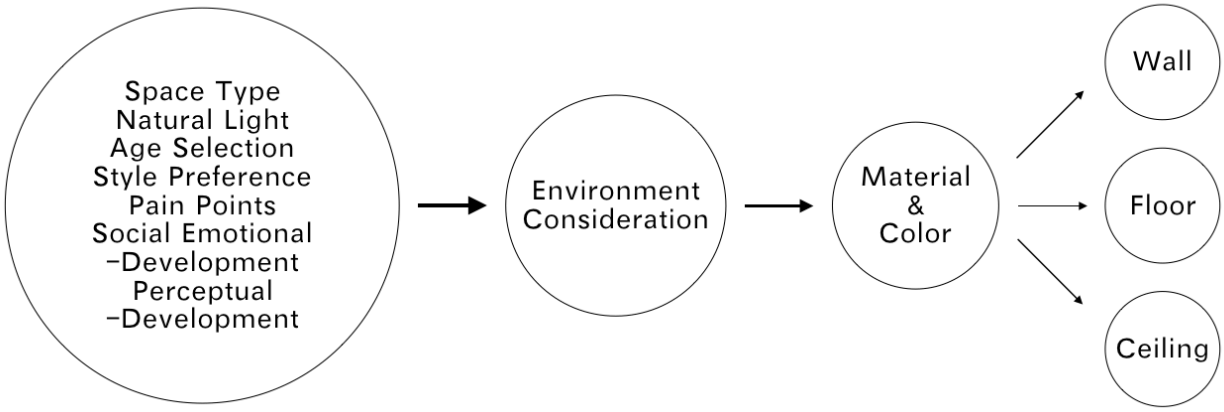


Figure 3.7 Environment Consideration

Influence Factors: Several factors can impact the reflection of space arrangement. These factors might include the space type, natural light, age selection, style preference, pain points, social emotional development, and perceptual development. The space type and natural light might decide the limitation of the brightness and lightness of the color. Also, because of the deliberation of security of the children, the hardness of the material surface should be taken into account. Designers need to look through space and user research thoroughly to make the accurate determination of environment consideration.

Approach: Designers can contribute some pictures of existing examples in children room design for parents. Parents can pick their favorite design style. Depending on the style, designers could analyze and extract the material and color that users prefer. They would use apply the material and color in the wall, floor, and ceiling.

Designers need to notice that the final material and color will be confirmed in this step, but the usability to wall, floor, and ceiling will be not settled. Designers can provide several

options for the proportion of the material and color application, and the final determination will be represented after the step of prefabrication creation.

Figure 3.8 Existing Examples of Children Room (IKEA, 2019)

Option / Function	Wall	Floor	Ceiling
1	Material A	Color A	Color B
2	Color A	Material A	Color B
3	Color B	Color A	Material A
4	Material A	Material A	Color A
5	Material A	Color B	Material A
6	Color A	Material A	Material A

Table 3.9 Options of Material and Color Application

3.2.1.3 Prefabrication Creation

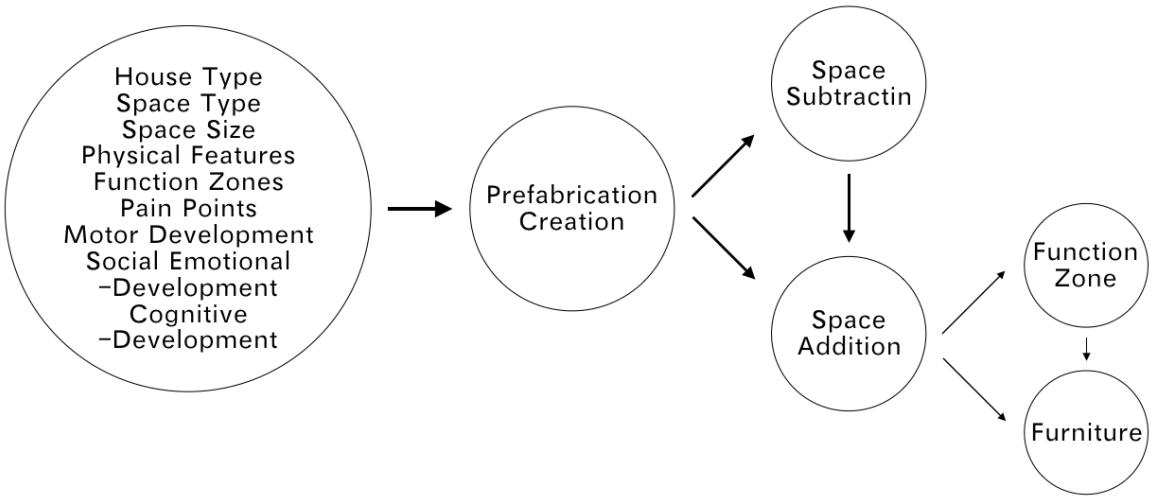


Figure 3.9 Prefabrication Creation

Influence Factors: This step will mainly base on the user research of table 3.5. Children's development needs in different age periods would primarily impact the reflection of prefabrication creation. Except for the development demands, the house type, space type, and pain points might influence the design of prefabricated products. Designers need to look through space and user research thoroughly to make the accurate determination of prefabrication creation.

Space Subtraction: There are two steps that designers need to take into account. The first one is space subtraction. This section would encourage designers to remove the unnecessary parts inside the room. Breaking the original layout of space might bring new opportunities.

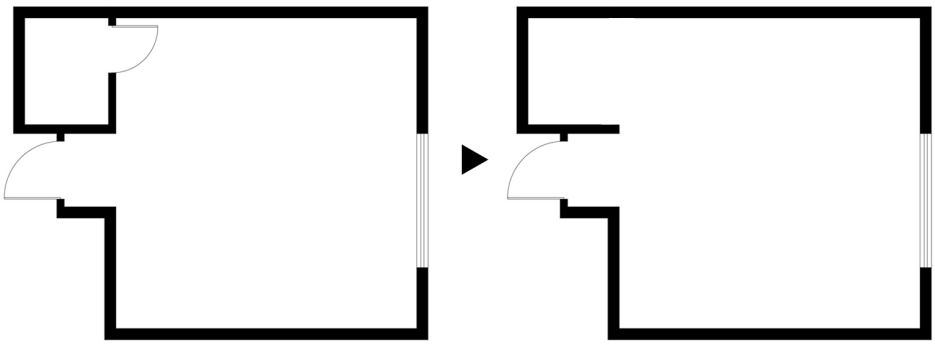


Figure 3.10 Example of Space Subtraction

Space Addition: The second one will be space addition. It would develop based on the new space that created on the last step. Designers are required to design new equipment, furniture, or products, which can meet the diverse need of children development. As the user research showed above, parents would choose the abilities or needs that they would like their children to develop in the particular age range. As Table 3.5 shows above, the abilities and needs are from motor development, perceptual development, social-emotional development, and cognitive development. It should be noticed that the concepts from designers should be flexible and multifunctional. They might have disassembled parts that can be easily transformed from one function to another function.

For example, children might need to cultivate the awareness of storage from the age of 3, but they can only recognize one categorization. With they get older, they would gradually recognize two to three categorizations. Before they enter school, the ability to distinguish different categorizations would form. Thus, designers can design a piece of storage furniture or system that have at least three different forms. The first one will have the lowest height with one ample space that children can put everything together. Then, the second one might have a higher

height than the first one with two or three drawers or cabinet. Finally, the third one would hold the various and complex categorized system.

As the representation, the space addition can be showed by the axonometric drawings. It can visually show the process of variation of the space from the beginning to the end.

3.2.1.4 Furniture Selection

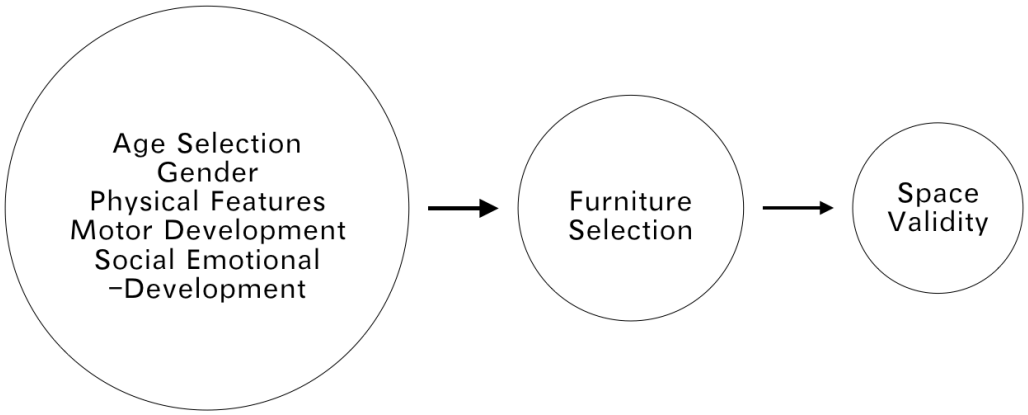


Figure 3.11 Furniture Selection

On the last step of concept generation, designers need to assist users to select proper furniture and simulate the final space situation. According to the simulation, users can visually know a particular function, style, and atmosphere of the children's room. Designers could use collage and rendering to express space design.

3.2.2 Evaluation Tool

The evaluation tool is a measure for the examination of different design concepts. Designers could use this tool to score their design concepts. The disadvantages and advantages of various concepts would be displayed for the users. Hence, users could make their final selection based on their interests and preferences. That is to say, even though the evaluation would

produce varying scores of concepts, users might not choose the highest score but choose their desired design concept. The evaluation tool could estimate the value of design concepts and help users to make the determination. However, it would not delimit the user's final selection.

This section would introduce the basic rules, grading contents, grading method, and calculation application of the evaluation tool in details. The basic rules would decipher the foundation and precondition of the tool. Then, the grading contents and grading method would help designers to understand how this tool works. Finally, based on the understanding of the evaluation tool, designers could quickly create the calculation table in Excel, and apply this table to complete ranking their concepts.

3.2.2.1 Basic Rules

Designer: The weights and scores for different ranking aspects are given by designers. Thus, as for one design concept, the evaluation tool should be used by the only designer himself or herself to ensure the standard and consistency of scores.

Design: According to the heterogeneity of weather, environment, resource, economic development, and culture, the interior design itself in various places would have big differences. Thus, designers in various places using this tool will produce inconsistent results. The final score of one design ranked by applying this evaluation tool from one designer could not be compared with another score of a design ranked by using this tool from another designer.

Evaluation: In order to process the comparison between multiple concepts, designers should at least create two distinct solutions for one problem.

Weights: The definition of weight should conform to user requirements. Designers should carefully complete the user research and reach an agreement with their user about the determination of the weights.

3.2.2.2 Grading Contents

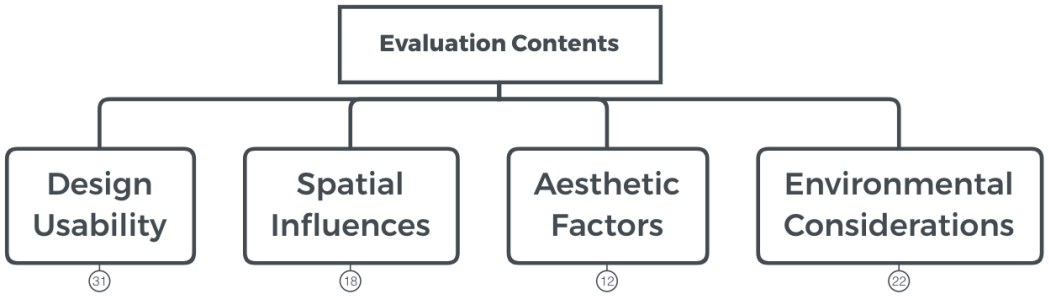


Figure 3.12 Evaluation Contents

The evaluation contents are mainly from the aspects that designers need to consider for the interior design. These contents represented in the literature review for the reference. There are four primary indicators: Design Usability, Spatial Influences, Aesthetic Factors, and Environmental Considerations. Therefore, designers would examine and rank their design concepts from the aspects of function, environment, form, and economy. These four indicators would be interpreted in detail in the following sections.

Design Usability: The most important aspect that designers need to consider is the utility. In order to better score the utility of design, the design usability is split into five factors: Function Solution, Using Comfort Level, Interactive Level, Users' Engagement, and Safety Level. This section will explain these contents in great details.

Function Solution is formed of the function needs (the design meets the primary demand of user), function display (the design clearly express its function and avoid misusing), multi-

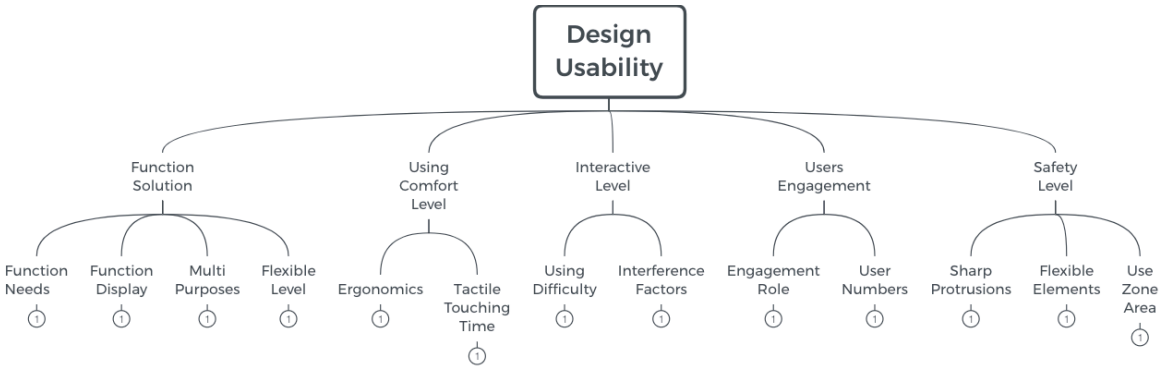


Figure 3.13 Design Usability

purpose means (the design could be used for other purposes), and flexibility level (the design is flexible enough to vary and adapt). Then, the Using Comfort Level is composed of the ergonomics (the design fits children's body well and help them work better), and tactile touching time (the time user would like to touch the surface of the design). Also, the Interactive Level is constituted of the using difficulty (if the design is easy for children to use or not), and interference factors (the number of interferences when children use the design). Moreover, the Users' Engagement is made of engagement role (the user's role when they use this design), and user numbers (the number that people could participate in using this design). Furthermore, the Safety Level is developed of the sharp protrusion (the number of sharp projection in the surface), flexible elements (the number of wires, cables, and other flexible items), and use zone area (the area that children need when they use the design).

Spatial Influences: Except for the utility of design, the effects that a design produces are also vital to consider. In order to objectively rank the effects of design, the designers need to consider the additional five factors: Acoustic Environment, Luminous Environment, Thermal Environment, Air Quality, and Space Arrangement.

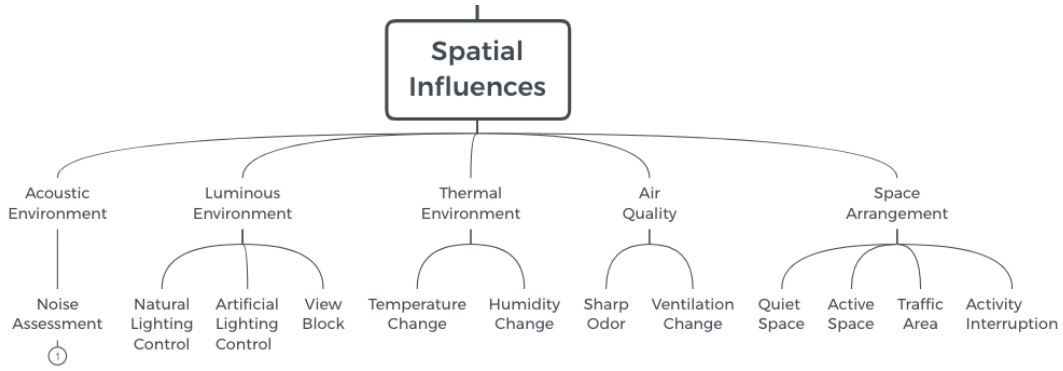


Figure 3.14 Spatial Influences

Acoustic Environment is formed of the noise assessment (the noise that the design brought when children are using it). Then, the Luminous Environment is composed of the natural lighting control (if the design will block the natural light or not), artificial lighting control (if the design will produce or block the artificial light or not) and view block (if the design will block children's view of the room). Moreover, the Thermal Environment is made of a temperature change (if the design makes the temperate more or less comfortable for children), and humidity(if the design makes the humidity more or less comfortable for children). Then, the Air Quality is constituted of the sharp odor (if the design smells sharp), and ventilation change (how the design affects the ventilation of the room). Finally, the Space Arrangement is examined by the Quiet Space (if the design affects the quiet space), Active Space (if the design affects the active space), Traffic Area (if the design affects the traffic space), and Activity Interruption (if the other activity will be interrupted when children are using the design).

Aesthetic Factors: Then, designers also need to consider the formal beauty of the design, and if the design visually and emotionally meets the user's interest and preference. The standards that are judging the aesthetics factors will be three factors: Color, Form, and Styling.

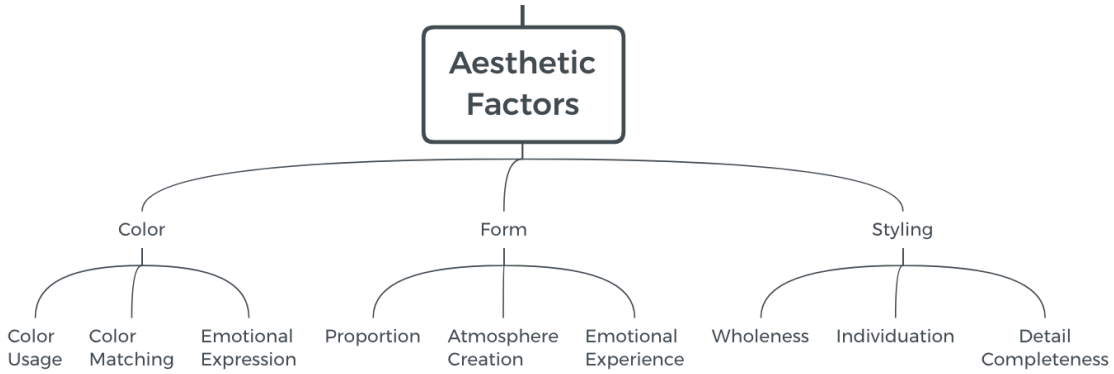


Figure 3.15 Aesthetic Factors

Color is formed of the color usage (if the color meets children's interest and functional needs), color matching (if the colors that are used in different places in the room match each other), and emotional expression (if the color correctly expresses the emotion that children need). Then, the Form is composed of the proportion (if the proportion brings beauty), atmosphere creation (if the design creates the atmosphere that children need) and emotional experience (if the design creates the emotional experience that children need). Finally, the Styling is examined by the wholeness (the completeness of a design), individuation (the characteristics of the room), and detail completeness(the detail processing of the room).

Environmental Considerations: Finally, designers need to examine if the design is green and carbon-conscious or not. The determination of the environmental considerations would include these four aspects: Material Durability, Material Environmental Protection, Service, and Cost.

Material Durability is formed of the abrasion resistance (the ability to resist abrasion), corrosion resistance (the ability to resist corrosion), and stability (the consistency of material in a long period of use). Then, the Material Environmental Protection is composed of the disposal

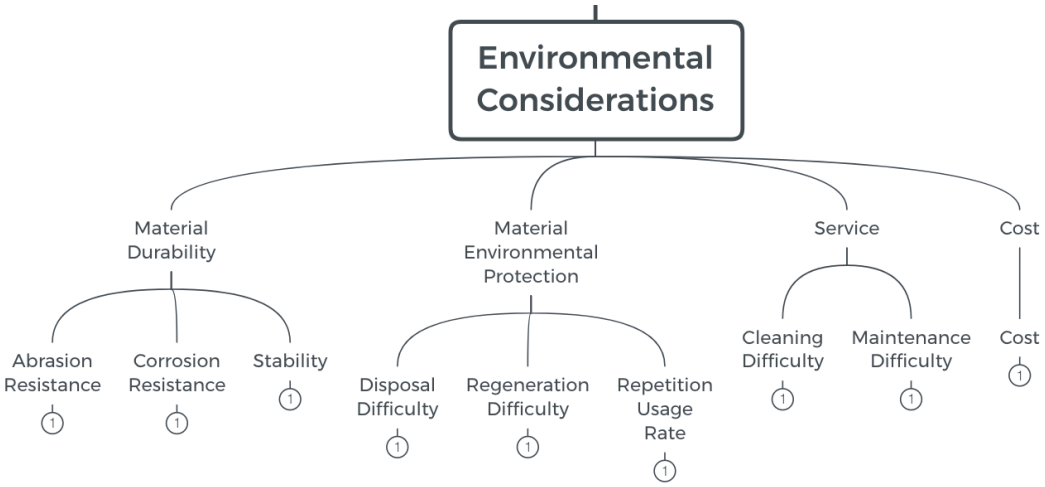


Figure 3.16 Environmental Considerations

difficulty (the difficulty of dealing with the material rubbish), regeneration difficulty (the difficulty of reproducing the material), and repetition usage rate (the rate that children could use the material many times). Moreover, the Service is made of the cleaning difficulty (the difficulty of cleaning the design), and maintenance difficulty (if the design needs to be fixed a lot). Finally, the Cost is examined by the total amount of the overhaul of the room.

3.2.2.3 Grading Method

After the grading contents, this section will discuss the rule of assigning weights and scores. At first, this section will interpret the general method that applied to the evaluation tool and the reason for choosing this method. Then, it will explain the calculation method in detail. According to the introduction, designers could know the principles of the grading method.

3.2.2.3.1 General Method

The evaluation method involves three indicators: the first class index, second class index, and third class index. The final evaluation of a concept design will be defined by the first class index, which contains Design Usability, Spatial Influences, Aesthetic Factors, and Environmental

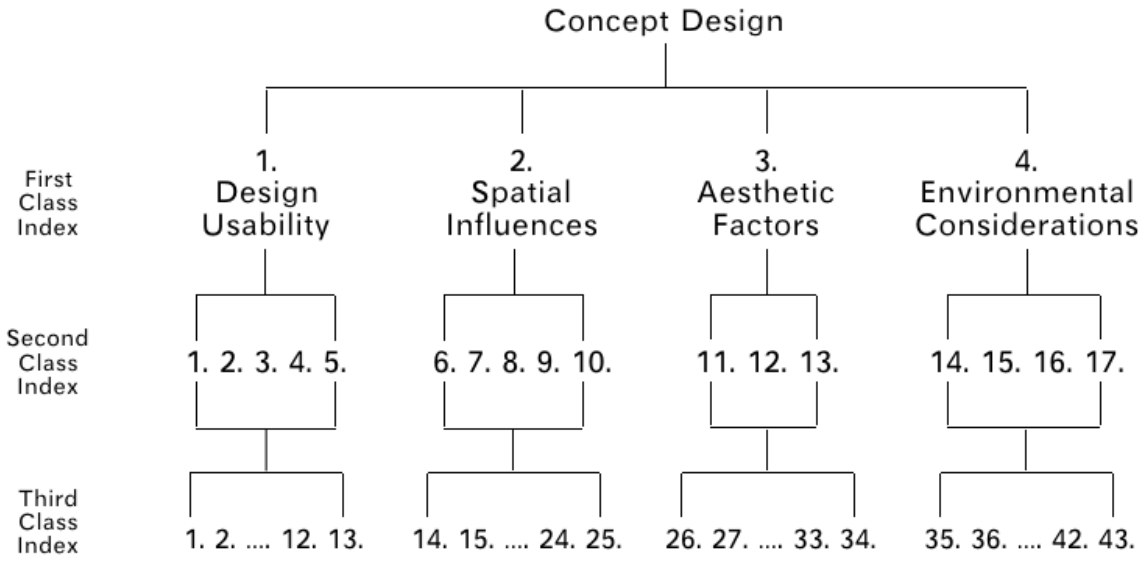


Figure 3.17 General Method

Considerations. The score of the first class index will be determined by the scores of the other 17 indicators, which are the second class index. Then, in order to objectively estimate these 17 indicators, designers need to apply the third class index, which has 43 indicators. In sum, the 43 indicators will be the factors that would affect the score of the final concept design the most. Next, the weights of the first, second, and third class indices will also influence the final score. The giving of weights will represent the importance of these indicators.

The designers should give both scores and weights to the third class index. According to the calculation of the scores and weights in the third class index, designers could possess the scores of the second class index. Then, designers should assign weights to the second class index. Based on the calculation of the weights and scores in the second class index, designers could get the scores of the first index class. Typically, as in the steps before, designers also need

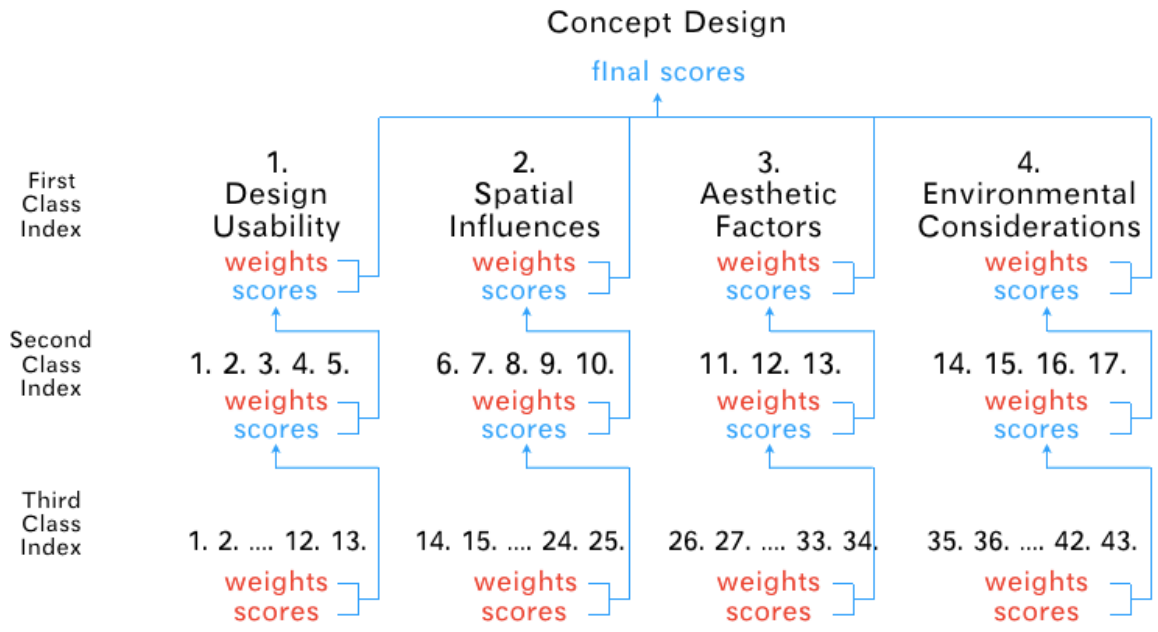


Figure 3.18 Concept Design

to supply the weights to the first class index. Finally, based on the weights and scores of the first class index, designers could ultimately get the final score of the concept design.

3.2.2.3.2 Calculation Method

This section will explain the calculation steps in detail from the third class index to the first class index. This section will start from the number one, two, three, and four indicators of the third class index to define the foundation of the calculation method. The introduction, formula, and the example will be described one by one.

Step One: In step one, designers should give both weights and scores to the third class index. The weights should be given from zero to ten according to the importance of the indicators. Also, the scores should be given from zero to one hundred according to the achievement of the particular indicators. In this step, designers should write down 43 weights

(score of the sum of no.1.2.3 and 4)			
(score of no.1)	(score of no.2)	(score of no.3)	(score of no.4)
1 Function Needs	2 Function Display	3 Multi Purposes	4 Flexible Level
(weight in 10)	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**
(sum of weight)			
(weight in %)	(weight in %)	(weight in %)	(weight in %)
(Designers score)	**(Designers score)**	**(Designers score)**	**(Designers score)**

Table 3.10 Introduction of Step One

and 43 scores based on the examination of the design. Next, designers are required to add the four weights together to get a sum of weights, then divide the sum into four weights to get the proportion of weight. Normally, designers need to calculate 17 times of addition and 43 times of division to the full third class index. Moreover, designers are required to multiply the four scores by the four proportions to get the final scores of the Function Needs, Function Display, Multi

s1'=w1*s1/ws1 + w2*s2/ws1 + w3*s3/ws1 + w4*s4/ws1			
w1*s1/ws1	w2*s2/ws1	w3*s3/ws1	w4*s4/ws1
1 Function Needs	2 Function Display	3 Multi Purposes	4 Flexible Level
w1	**w2**	**w3**	**w4**
ws1=w1+w2+w3+w4			
w1/ws1	w2/ws1	w3/ws1	w4/ws1
s1	**s2**	**s3**	**s4**

Table 3.11 Formula of Step One

purposes, and Flexible level. Typically, designers should do the multiplication for 43 times. Finally, designers need to add all the final scores of the third class index together to get the sum, which is the score of the second class index. The addition of the final scores will be repeated 17 times.

Table of the formula of step one is shown above. The w1, w2, w3, and w4 represent the weights that designers give to the third class index. The s1, s2, s3, and s4 represent the scores that designers give to the concept design depending on the standards of the third class index. The ws1 means the sum of weights which formed by the w1, w2, w3, and w4. Then, when designers get the ws1, they can calculate the proportion of weights, which are w1/ws1, w2/ws1, w3/ws1, and w4/ws1. Next, designers need to multiply the proportion by the s1, s2, s3, and s4. At final, designers will get the s1, which is the sum of the w1*s1/ws1, w2*s2/ws1, w3*s3/ws1, and w4*s4/ws1.

77.2307692307692			
27.0769230769	17.5384615384	14.0384615384	18.5769230769
1 Function Needs	2 Function Display	3 Multi Purposes	4 Flexible Level
8	6	5	7
26			
0.30769230769	0.23076923076	0.19230769230	0.26923076923
88	76	73	69

Table 3.12 Example of Step One

The example in step one shows that designers give the weights eight for the Function Needs, six for the Function Display, five for the Multi Purposes, and seven for the Flexible Level. The weights mean that designers think that function need is the most critical factor in the design compared to the other factors. Also, designers write down the scores 88 for the Function Needs, 76 for the Function Display, 73 for the Multi Purposes, and 69 for the Flexible Level. These four indicators belong to the Functional Solution which is the second class index. Hence, after the calculation, designers could obtain the final score for Function Solution, which is about 77.2. Using on the same calculation method, designers could also get the scores of Using Comfort Level, Interactive Level, Users Engagement, and Safety Level.

(score of the sum of Function Solution, Using Comfort Level, Interactive Level, Users Engagement and Safety Level)				
(score of Function Solution)	(score of Using Comfort Level)	(score of Interactive Level)	(score of Users Engagement)	(score of Safety Level)
1 Function Solution	2 Using Comfort Level	3 Interactive Level	4 Users Engagement	5 Safety Level
(weight in 10)	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**
(sum of weight)				
(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)
(score of the sum of no.1. 2. 3 and 4)	(score of the sum of no.5 and 6)	(score of the sum of no.7 and 8)	(score of the sum of no.9 and 10)	(score of the sum of no.11.12 and 13)

Table 3.13 Introduction of Step Two

Step Two: After calculating the third class index, designers then need to calculate the score of second class index. The second class index will be in total 17 indicators, which starts from the Function Solution to the Cost.

In step two, designers should give only weights to the second class index. The weights also should be given from zero to ten according to the importance of the indicators. Depending

on the calculation of step one, designers should already know the sum of the scores of the third class index, which are shown in the bottom in Table 3.8. Normally, in this step, designers should write down 17 weights based on the examination of the design. Taking the Function Solution, Using Comfort Level, Interactive Level, Users Engagement, and Safety Level as an example, designers are required to add the five weights together to get a sum of weights, then divide the sum into five weights to get the proportion of weight. Usually, designers need to calculate four times of addition and 17 times of division to the full second class index. Moreover, designers are required to multiply the five scores by the five proportions to get the final scores of the Function Solution, Using Comfort Level, Interactive Level, Users Engagement, and Safety Level. Typically, designers should do the multiplication 17 times. Finally, designers need to add all the final scores of the second class index together to get the sum, which is the score of the first class index. The addition of the final scores will be repeated four times.

s1”=w1’*s1’/ws1’ + w2’*s2’/ws2’ + w3’*s3’/ws3’ + w4’*s4’/ws4’ + w5’*s5’/ws5’				
w1’*s1’/ws1’	w2’*s2’/ws2’	w3’*s3’/ws3’	w4’*s4’/ws4’	w5’*s5’/ws5’
1 Function Solution	2 Using Comfort Level	3 Interactive Level	4 Users Engagement	5 Safety Level
w1’	**w2’**	**w3’**	**w4’**	**w5’**
ws1’=w1’+w2’+w3’+w4’+w5’				
w1’/ws1’	w2’/ws2’	w3’/ws3’	w4’/ws4’	w5’/ws5’
s1’=w1*s1/ws1 + w2*s2/ws1 + w3*s3/ws1 + w4*s4/ws1	s2’=w5*s5/ws2 + w6*s6/ws2	s3’=w7*s7/ws3 + w8*s8/ws3	s4’=w9*s9/ws4 + w10*s10/ws4	s5’=w11*s11/ws5 + w12*s12/ws5 + w13*s13/ws5

Table 3.14 Formula of Step Two

The formula of step two is shown above. The w1’, w2’, w3’, w4’, and w5’ represent the weights that designers give to the second class index. The s1’, s2’, s3’, s4’ and s5’ represent the

scores that designers calculated from the step one. The ws1' means the sum of weights which added from the w1', w2', w3', w4' and w5'. Then, when designers get the ws1', they can calculate the proportion of weights, which are w1'/ws1', w2'/ws1', w3'/ws1', w4'/ws1' and w5'/ws1'. Next, designers need to multiply the proportion by the s1', s2', s3', s4' and s5', which are calculated from step one. Finally, designers will get the s1'', which is the sum of the w1'*s1'/ws1', w2'*s2'/ws1', w3'*s3'/ws1', w4'*s4'/ws1' and w5'*s5'/ws1'.

74.4415628815629				
19.8593406593407	18.8342857142857	10.44	10.6507936507936	14.6571428571429
1 Function Solution	2 Using Comfort Level	3 Interactive Level	4 Users Engagement	5 Safety Level
9	8	7	5	6
35				
0.257142857142857	0.228571428571429	0.2	0.142857142857143	0.171428571428571
77.2307692307692	82.4	52.2	74.5555555555555	85.5

Table 3.15 Example of Step Two

The example in step two shows that designers give the weights nine for the Function Solution, eight for the Using Comfort Level, seven for the Interactive Level, five for the Users Engagement and six for the Safety Level. The weights mean that designers think that the Function Solution is the most critical factor in the design than the other factors. Also, according to the calculation of step one, designers have gotten the approximate scores 77.2 for the Function Solution, 82.4 for the Using Comfort Level, 52.2 for the Interactive Level, 74.6 for the Users Engagement, and 85.5 for the Safety Level. The particular calculation method of the Function Solution has been shown in step one in detail; the calculation method of other indicators in the

second class index should also follow the example in step one. These five indicators belong to the Design Usability, which is in the first class index. Hence, after the calculation, designers could obtain the final score for Design Usability, which is about 74.4. Depending on the same calculation method, designers could also get the scores of Spatial Influences, Aesthetic Factors, and Environmental Considerations.

(Final Score)			
(score of Design Usability)	(score of Spatial Influences)	(score of Aesthetic Factors)	(score of Environmental Considerations)
1 Design Usability	2 Spatial Influences	3 Aesthetic Factors	4 Environmental Considerations
(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)
(sum of weight)			
(weight in %)	(weight in %)	(weight in %)	(weight in %)
(score of the sum of Function Solution, Using Comfort Level, Interactive Level, Users Engagement and Safety Level)	(score of the sum of Acoustic Environment, Luminous Environment, Thermal Environment, Air Quality and Space Arrangement)	(score of the sum of Color, Form and Styling)	(score of the sum of Material Durability, Material Environmental Protection, Service and Cost)

Table 3.16 Introduction of Step Three

Step Three: After calculating the second class index, designers then need to calculate the score of first class index. The first class index will be in total four indicators, which start from the Design Usability to the Environmental Considerations.

In step three, designers should give only weights to the first class index, which are the Design Usability, Spatial Influences, Aesthetic Factors, and Environmental Considerations. The weights also should be given from zero to ten according to the importance of the indicators. Depending on the calculation of step second, designers should have already know the sum of the scores of the second class index, which is shown in the bottom in Table 3.11. Designers are required to add the four weights together to get a sum of weight, then divide the sum into four weights to get the proportion of weight. Usually, designers need to calculate only one time of

addition and four times of division to the full first class index. Moreover, designers are required to multiply the four scores by the four proportions to get the final scores of the Design Usability, Spatial Influences, Aesthetic Factors, and Environmental Considerations. Typically, designers should do the multiplication four times. Finally, designers need to add all the final scores of the first class index together to get the sum, which is the final score of the concept design.

fs=w1”*s1”/ws + w2”*s2”/ws + w3”*s3”/ws + w4”*s4”/ws			
w1”*s1”/ws	w2”*s2”/ws	w3”*s3”/ws	w4”*s4”/ws
1 Design Usability	2 Spatial Influences	3 Aesthetic Factors	4 Environmental Considerations
w1”	w2”	w3”	w4”
ws=ws1”+ws2”+w3”+w4”			
w1”/ws	w2”/ws	w3”/ws	w4”/ws
s1”=w1’*s1’/ws1’ + w2’*s2’/ws2’ + w3’*s3’/ws3’ + w4’*s4’/ws4’ + w5’*s5’/ws5’	s2”=w6’*s6’/ws6’ + w7’*s7’/ws7’ + w8’*s8’/ws8’ + w9’*s9’/ws9’ + w10’*s10’/ws10’	s3”=w11’*s11’/ws11’ + w12’*s12’/ ws12’ + w13’*s13’/ws13’	s4”=w14’*s14’/ws14’ + w15’*s15’/ ws15’ + w16’*s16’/ws16’ + w17’*s17’/ ws17’

Table 3.17 Formula of Step Three

Table of the formula of step three is shown above. The w1’’, w2’’, w3’’, and w4’’ represent the weights that designers give to the first class index. The s1’’, s2’’, 3’’, and s4’’ represent the scores that designers calculated from the step two. The ws means the sum of weights which added from the w1’’, w2’’, w3’’, and w4’’. Then, when designers get the ws, they can calculate the proportion of weights, which are w1’’/ws, w2’’/ws, w3’’/ws, and w4’’/ws. Next, designers need to multiply the proportion by the s1’’, s2’’, s3’’, and s4’’, which are calculated from the step two. Finally, designers will get the fs, which is the sum of the w1’’*s1’’/ws, w2’’*s2’’/ws, w3’’*s3’’/ws, and w4’’*s4’’/ws.

The example in step three shows that designers give the weights nine for the Design Usability, seven for the Spatial Influences, six for the Aesthetic Factors, and eight for the

74.8642548192548			
22.3324688644689	17.5242222222222	14.5117489177489	20.4958148148148
1 Design Usability	2 Spatial Influences	3 Aesthetic Factors	4 Environmental Considerations
9	7	6	8
30			
0.3	0.233333333333333	0.2	0.266666666666667
74.4415628815629	75.1038095238095	72.5587445887446	76.8593055555556

Table 3.18 Example of Step Three

Environmental Considerations. The weights mean that designers think that the Design Usability is the most critical factor in the design compared to the other factors. Also, according to the calculation of step two, designers have gotten the approximate scores 74.4 for the Design Usability, 75.1 for the Spatial Influences, 72.6 for the Spatial Influences, and 76.9 for the Environmental Considerations. The particular calculation method of the Design Usability has been shown in the step two in detail; the calculation method of other indicators in the first class index should also follow the example in step two. These four indicators will result in the final score of concept design. Hence, after the calculation, designers could obtain the final score for the concept design, which is about 74.9.

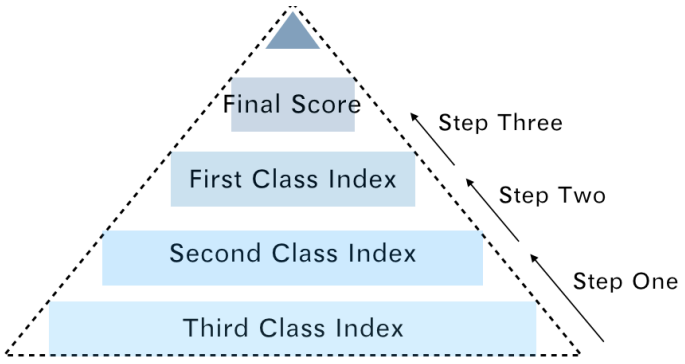


Figure 3.19 Evaluation Conclusion

Conclusion: This section mainly explains the grading method providing the introduction, formula, and example of the calculation. If the full grading method is a pyramid structure, than designers need to apply the method from the bottom to the top.

3.2.2.4 Calculation Application

After the introduction of the basic rules, grading contents, and grading method, this section will address how to utilize these principles in practical concepts. At first, designers need to write down the weights and scores for the concept design into the weights and scores table. Then, designers are required to create a calculation table with particular formulas in Excel, so that they could quickly get the results of the calculation through directly typing these weights and scores in the calculation table in Excel.

Designers should define the weights for the first, second, and third class index, and also the scores for the third class index. In total, designers should write down four weights for the first class index, 17 weights for the second class index, and 43 weights for the third class index. Then, designers need to determine 43 scores for the third class index. When the users agree with the decision, designers could fill out Table 3.14 and Table 3.15.

After filling out the tables, designers need to create an Excel table for calculation. Table 3.16 displays the arrangement and purpose of the Excel table. When designers finish creating the structure, they need to add the formulas into these blanks. Table 3.17 explains how to build these formulas. The precise explanation is presented in the section of the Calculation Method. Then, Table 3.18 depicts an example of the Excel table. Designers need to type the weights into the orange rows and scores into the pink rows. Next, the final score will be shown in the blue row on the top of the table.

Table of Weights

Weight Table_First Class Index				
Indicators	1 Design Usability	2 Spatial Influences	3 Aesthetic Factors	4 Environmental Considerations
Weight				

Weight Table _ Second Class Index_Design Usability					
Indicators	1 Function Solution	2 Using Comfort Level	3 Interactive Level	4 Users Engagement	5 Safety Level
Weight					

Weight Table _ Second Class Index_Spatial Influences					
Indicators	6 Acoustic Environment	7 Luminous Environment	8 Thermal Environment	9 Air Quality	10 Space Arrangement
Weight					

Weight Table _ Second Class Index_Aesthetic Factors			
Indicators	11 Color	12 Form	13 Styling
Weight			

Weight Table _ Second Class Index_Environmental Considerations				
Indicators	14 Material Durability	15 Material Environmental Protection	16 Service	17 Cost
Weight				

1

Table 3.19 Weights for the First and Second Class Index

Table of Weights and Scores

	Weight Table _ Third Class Index												
Indicators	1 Function Solution				2 Using Comfort Level		3 Interactive Level		4 Users Engagement		5 Safety Level		
Indicators	1 Function Needs	2 Function Display	.3 Multi Purposes	4 Flexible Level	5 Ergonomics	6 Tactile Touching Time	7 Using Difficulty	8 Interference Factors	9 Engagement Role	10 User Numbers	11 Sharp Protrusions	12 Flexible Elements	13 Use Zone Area
Weight													
Score													

	Weight Table _ Third Class Index											
Indicators	6 Acoustic Environment	7 Luminous Environment			8 Thermal Environment		9 Air Quality		10 Space Arrangement			
Indicators	14 Noise Assessment	15 Natural Lighting Control	16 Artificial Lighting Control	17 View Block	18 Temperature Change	19 Humidity Change	20 Sharp Odor	21 Ventilation Change	22 Quiet Space	23 Active Space	24 Traffic Area	25 Activity Interruption
Weight												
Score												

	Weight Table _ Third Class Index								
Indicators	11 Color			12 Form			13 Styling		
Indicators	26 Color Usage	27 Color Matching	28 Emotional Expression	29 Proportion	30 Atmosphere Creation	31 Emotional Experience	32 Wholeness	33 Individuation	34 Detail Completeness
Weight									
Score									

	Weight Table _ Third Class Index								
Indicators	14 Material Durability			15 Material Environmental Protection			16 Service		17 Cost
Indicators	35 Abrasion Resistance	36 Corrosion Resistance	37 Stability	38 Disposal Difficulty	39 Regeneration Difficulty	40 Repetition Usage Rate	41 Cleaning Difficulty	42 Maintenance Difficulty	43 Cost
Weight									
Score									

2

Table 3.20 Weights and Scores for the Third Class Index

(score of Aesthetic Factors)									(score of Environmental Considerations)								
3 Aesthetic Factors									4 Environmental Considerations								
(weight in 10)									**(weight in 10)**								
(weight in %)									(weight in %)								
(score of the sum of Color, Form and Styling)									(score of the sum of Material Durability, Material Environmental Protection, Service and Cost)								
(score of Color)			(score of Form)			(score of Styling)			(score of Material Durability)			(score of Material Environmental Protection)			(score of Service)		(score of Cost)
11 Color			12 Form			13 Styling			14 Material Durability			15 Material Environmental Protection			16 Service		17 Cost
(weight in 10)			**(weight in 10)**			**(weight in 10)**			**(weight in 10)**			**(weight in 10)**			**(weight in 10)**		**(weight in 10)**
(sum of weight)									(sum of weight)								
(weight in %)			(weight in %)			(weight in %)			(weight in %)			(weight in %)			(weight in %)		(weight in %)
(score of the sum of no.26.27 and 28)			(score of the sum of no.29.30 and 31)			(score of the sum of no.32.33 and 34)			(score of the sum of no.35.36 and 37)			(score of the sum of no.38.39 and 40)			(score of the sum of no.41 and 42)		(score of no.43)
(score of no.26)	(score of no.27)	(score of no.28)	(score of no.29)	(score of no.30)	(score of no.31)	(score of no.32)	(score of no.33)	(score of no.34)	(score of no.35)	(score of no.36)	(score of no.37)	(score of no.38)	(score of no.39)	(score of no.40)	(score of no.41)	(score of no.42)	(score of no.43)
26 Color Usage	27 Color Matching	28 Emotional Expression	29 Proportion	30 Atmosphere Creation	31 Emotional Experience	32 Wholeness	33 Individuation	34 Detail Completeness	35 Abrasion Resistance	36 Corrosion Resistance	37 Stability	38 Disposal Difficulty	39 Regeneration Difficulty	40 Repetition Usage Rate	41 Cleaning Difficulty	42 Maintenance Difficulty	43 Cost
(weight in 10)	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**	**(weight in 10)**
(sum of weight)			(sum of weight)			(sum of weight)			(sum of weight)			(sum of weight)			(sum of weight)		(sum of weight)
(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)
(Designers score)	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**	**(Designers score)**

Structure of Calculation Table

(Final Score)																								
(score of Design Usability)													(score of Spatial Influences)											
1 Design Usability													2 Spatial Influences											
(weight in 10)													(weight in 10)											
													(sum of weight)											
(weight in %)													(weight in %)											
(score of the sum of Function Solution, Using Comfort Level, Interactive Level, Users Engagement and Safety Level)													(score of the sum of Acoustic Environment, Luminous Environment, Thermal Environment, Air Quality and Space Arrangement)											
(score of Function Solution)				(score of Using Comfort Level)		(score of Interactive Level)		(score of Users Engagement)		(score of Safety Level)			(score of Acoustic Environment)	(score of Luminous Environment)			(score of Thermal Environment)		(score of Air Quality)		(score of Space Arrangement)			
1 Function Solution				2 Using Comfort Level		3 Interactive Level		4 Users Engagement		5 Safety Level			6 Acoustic Environment	7 Luminous Environment			8 Thermal Environment		9 Air Quality		10 Space Arrangement			
(weight in 10)				(weight in 10)		(weight in 10)		(weight in 10)		(weight in 10)			(weight in 10)	(weight in 10)			(weight in 10)		(weight in 10)		(weight in 10)			
(sum of weight)													(sum of weight)											
(weight in %)				(weight in %)		(weight in %)		(weight in %)		(weight in %)			(weight in %)	(weight in %)			(weight in %)		(weight in %)		(weight in %)			
(score of the sum of no.1. 2. 3 and 4)				(score of the sum of no.5 and 6)		(score of the sum of no.7 and 8)		(score of the sum of no.9 and 10)		(score of the sum of no.11.12 and 13)			(score of no.14)	(score of the sum of no.15.16 and 17)			(score of the sum of no.18 and 19)		(score of the sum of no.20 and 21)		(score of the sum of no.22.23.24 and 25)			
(score of no.1)	(score of no.2)	(score of no.3)	(score of no.4)	(score of no.5)	(score of no.6)	(score of no.7)	(score of no.8)	(score of no.9)	(score of no.10)	(score of no.11)	(score of no.12)	(score of no.13)	(score of no.14)	(score of no.15)	(score of no.16)	(score of no.17)	(score of no.18)	(score of no.19)	(score of no.20)	(score of no.21)	(score of no.22)	(score of no.23)	(score of no.24)	(score of no.25)
1 Function Needs	2 Function Display	3 Multi Purposes	4 Flexible Level	5 Ergonomics	6 Tactile Touching Time	7 Using Difficulty	8 Interference Factors	9 Engagement Role	10 User Numbers	11 Sharp Protrusions	12 Flexible Elements	13 Use Zone Area	14 Noise Assessment	15 Natural Lighting Control	16 Artificial Lighting Control	17 View Block	18 Temperature Change	19 Humidity Change	20 Sharp Odor	21 Ventilation Change	22 Quiet Space	23 Active Space	24 Traffic Area	25 Activity Interruption
(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)	(weight in 10)
(sum of weight)				(sum of weight)		(sum of weight)		(sum of weight)		(sum of weight)			(sum of weight)	(sum of weight)			(sum of weight)		(sum of weight)		(sum of weight)			
(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)	(weight in %)
(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)	(Designers score)

Table 3.21 Structure of Calculation Table

w3”*s3”/ws	w4”*s4”/ws
3 Aesthetic Factors	4 Environmental Considerations
w3”	**w4”**
w3”/ws	w4”/ws
s3”=w11’*s11’/ws11’ + w12’*s12’/ws12’ + w13’*s13’/ws13’	s4”=w14’*s14’/ws14’ + w15’*s15’/ws15’ + w16’*s16’/ws16’ + w17’*s17’/ws17’

w11’*s11’/ws3’	w12’*s12’/ws3’	w13’*s13’/ws3’	w14’*s14’/ws4’	w15’*s15’/ws4’	w16’*s16’/ws4’	w17’*s17’/ws4’
11 Color	12 Form	13 Styling	14 Material Durability	15 Material Environmental Protection	16 Service	17 Cost
w11’	**w12’**	**w13’**	**w14’**	**w15’**	**w16’**	**w17’**
ws3’=w11’+w12’+w13’			ws4’=w14’+w15’+w16’+w17’			
w11’/ws3’	w12’/ws3’	w13’/ws3’	w14’/ws4’	w15’/ws4’	w16’/ws4’	w17’/ws4’
w26*s26/ws11+w27*s27/ws11+w28*s28/ws11	s12’=w29*s29/ws12+w30*s30/ws12+w31*s31/ws12	s13’=w32*s32/ws13+w33*s33/ws13+w34*s34/ws13	s14’=w35*s35/ws14+w36*s36/ws14+w37*s37/ws14	s15’=w38*s38/ws15+w39*s39/ws15+w40*s40/ws15	s16’=w41*s41/ws16+w42*s42/ws16	s17’

;26 1	w27*s27 /ws11	w28*s28 /ws11	w29*s29 /ws12	w30*s30 /ws12	w31*s31 /ws12	w32*s32 /ws13	w33*s33 /ws13	w34*s34 /ws13	w35*s35 /ws14	w36*s36 /ws14	w37*s37 /ws14	w38*s38 /ws15	w39*s39 /ws15	w40*s40 /ws15	w41*s41 /ws16	w42*s42 /ws16	w43*s43 /ws17
or ge	27 Color Matching	28 Emotional Expression	29 Proportion	30 Atmosphere Creation	31 Emotional Experience	32 Wholeness	33 Individuation	34 Detail Completeness	35 Abrasion Resistance	36 Corrosion Resistance	37 Stability	38 Disposal Difficulty	39 Regeneration Difficulty	40 Repetition Usage Rate	41 Cleaning Difficulty	42 Maintenance Difficulty	43 Cost
s	**w27**	**w28**	**w29**	**w30**	**w31**	**w32**	**w33**	**w34**	**w35**	**w36**	**w37**	**w38**	**w39**	**w40**	**w41**	**w42**	**w43**
/s11=w26+w27+w28			ws12=w29+w30+w31			ws13=w32+w33+w34			ws14=w35+w36+w37			ws15=w38+w39+w40			ws16=w41+w42		ws17=w43
;/ 1	w27/ ws11	w28/ ws11	w29/ ws12	w30/ ws12	w31/ ws12	w32/ ws13	w33/ ws13	w34/ ws13	w35/ ws14	w36/ ws14	w37/ ws14	w38/ ws15	w39/ ws15	w40/ ws15	w41/ ws16	w42/ ws16	w43/ ws16
s	**s27**	**s28**	**s29**	**s30**	**s31**	**s32**	**s33**	**s34**	**s35**	**s36**	**s37**	**s38**	**s39**	**s40**	**s41**	**s42**	**s43**

fs=w1"*s1"/ws + w2"*s2"/ws + w3"*s3"/ws + w4"*s4"/ws																								
w1"*s1"/ws													w2"*s2"/ws											
1 Design Usability													2 Spatial Influences											
w1"													w2"											
ws=ws1"+ws2"+w3"+w4"																								
w1"/ws													w2"/ws											
s1"=w1'*s1'/ws1' + w2'*s2'/ws2' + w3'*s3'/ws3' + w4'*s4'/ws4' + w5'*s5'/ws5'													s2"=w6'*s6'/ws6' + w7'*s7'/ws7' + w8'*s8'/ws8' + w9'*s9'/ws9' + w10'*s10'/ws10'												
w1'*s1'/ws1'				w2'*s2'/ws1'		w3'*s3'/ws1'		w4'*s4'/ws1'		w5'*s5'/ws1'			w6'*s6'/ws2'	w7'*s7'/ws2'				w8'*s8'/ws2'		w9'*s9'/ws2'		w10'*s10'/ws2'			
1 Function Solution				2 Using Comfort Level		3 Interactive Level		4 Users Engagement		5 Safety Level			6 Acoustic Environment	7 Luminous Environment				8 Thermal Environment		9 Air Quality		10 Space Arrangement			
w1'				w2'		w3'		w4'		w5'			w6'	w7'				w8'		w9'		w10'			
ws1'=w1'+w2'+w3'+w4'+w5'													ws2'=w6'+w7'+w8'+w9'+w10'											
w1'/ws1'				w2'/ws1'		w3'/ws1'		w4'/ws1'		w5'/ws1'			w6'/ws2'	w7'/ws2'				w8'/ws2'		w9'/ws2'		w10'/ws2'			
s1'=w1*s1/ws1 + w2*s2/ws1 + w3*s3/ws1 + w4*s4/ws1				s2'=w5*s5/ws2 + w6*s6/ws2		s3'=w7*s7/ws3 + w8*s8/ws3		s4'=w9*s9/ws4 + w10*s10/ws4		s5'=w11*s11/ws5 + w12*s12/ws5 + w13*s13/ws5			s6'	s7'=w15*s15/ws7+w16*s16/ws7+w17*s17/ws7				s8'=w18*s18/ws8+w19*s19/ws8		s9'=w20*s20/ws9+w21*s21/ws9		s10'=w22*s22/ws10+w23*s23/ws10+w24*s24/ws10+w25*s25/ws1			
w1*s1/ws1	w2*s2/ws1	w3*s3/ws1	w4*s4/ws1	w5*s5/ws2	w6*s6/ws2	w7*s7/ws3	w8*s8/ws3	w9*s9/ws4	w10*s10/ws4	w11*s11/ws5	w12*s12/ws5	w13*s13/ws5	w14*s14/ws6	w15*s15/ws7	w16*s16/ws7	w17*s17/ws7	w18*s18/ws8	w19*s19/ws8	w20*s20/ws9	w21*s21/ws9	w22*s22/ws10	w23*s23/ws10	w24*s24/ws10	w25'/ws
1 Function Needs	2 Function Display	3 Multi Purposes	4 Flexible Level	5 Ergonomics	6 Tactile Touching Time	7 Using Difficulty	8 Interference Factors	9 Engagement Role	10 User Numbers	11 Sharp Protrusions	12 Flexible Elements	13 Use Zone Area	14 Noise Assessment	15 Natural Lighting Control	16 Artificial Lighting Control	17 View Block	18 Temperature Change	19 Humidity Change	20 Sharp Odor	21 Ventilation Change	22 Quiet Space	23 Active Space	24 Traffic Area	25 Activi Interi or
w1	w2	w3	w4	w5	w6	w7	w8	w9	w10	w11	w12	w13	w14	w15	w16	w17	w18	w19	w20	w21	w22	w23	w24	w2
ws1=w1+w2+w3+w4				ws2=w5+w6		ws3=w7+w8		ws4=w9+w10		ws5=w11+w12+w13			ws6=w14	ws7=w15+w16+w17			ws8=w18+w19		ws9=w20+w21		ws10=w22+w23+w24+w25			
w1/ws1	w2/ws1	w3/ws1	w4/ws1	w5/ws2	w6/ws2	w7/ws3	w8/ws3	w9/ws4	w10/ws4	w11/ws5	w12/ws5	w13/ws5	w14/ws6	w15/ws7	w16/ws7	w17/ws7	w18/ws8	w19/ws8	w20/ws9	w21/ws9	w22/ws10	w23/ws10	w24/ws10	w2 ws
s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	s13	s14	s15	s16	s17	s18	s19	s20	s21	s22	s23	s24	s2

Table 3.22 Formula of Calculation Table

14.5117489177489									20.4958148148148								
3 Aesthetic Factors									4 Environmental Considerations								
6									8								
0.2									0.266666666666667								
72.5587445887446									76.8593055555556								
27.352380952381			18.8363636363636			26.37			22.2222222222222			21.0933333333333			17.94375		15.6
Color			Form			Styling			Material Durability			Material Environmental Protection			Service		Cost
8			8			9			8			7			9		6
25									30								
0.32			0.32			0.36			0.266666666666667			0.233333333333333			0.3		0.2
85.4761904761905			58.8636363636364			73.25			83.3333333333333			90.4			59.8125		78
35.809523	29.666666	20	27.818181	16.090909	14.954545	22	28.5	22.75	26.333333	23.625	33.375	37.2	30	23.2	34.875	24.9375	78
26 Color Usage	27 Color Match -ing	28 Emo -tional Expres -sion	29 Propor -tion	30 Atmos -phere Creation	31 Emo -tional Experi -ence	32 Whole -ness	33 Individua -tion	34 Detail Comple -teness	35 Abrasion Resis -tance	36 Corro -sion Resis -tance	37 Stability	38 Disposal Difficulty	39 Regene -ration Difficulty	40 Repeti -tion Usage Rate	41 Cleaning Difficulty	42 Main -tenance Difficulty	43 Cost
8	7	6	9	6	7	8	9	7	8	7	9	6	5	4	9	7	8
21			22			24			24				15		16		8
0.380952	0.333333	0.285714	0.409090	0.272727	0.318181	0.333333	0.375	0.291666	0.333333	0.291666	0.375	0.4	0.333333	0.266666	0.5625	0.4375	1
94	89	70	68	59	47	66	76	78	79	81	89	93	90	87	62	57	78

Example of Calculation Table

74.8642548192548																								
22.3324688644689													17.5242222222222											
1 Design Usability													2 Spatial Influences											
9													7											
30																								
0.3													0.233333333333333											
74.4415628815629													75.1038095238095											
19.8593406593407				18.8342857142857		10.44		10.6507936507936		14.6571428571429			13.2	12.0380952380952			12.2142857142857		16.1714285714286		21.48			
1 Function Solution				2 Using Comfort Level		3 Interactive Level		4 Users Engagement		5 Safety Level			Acoustic Environment	Luminous Environment			Thermal Environment		Air Quality		Space Arrangement			
9				8		7		5		6			7	6			5		8		9			
35													35											
0.257142857142857				0.228571428571429		0.2		0.142857142857143		0.171428571428571			0.2	0.171428571428571			0.142857142857143		0.228571428571429		0.257142857142857			
77.2307692307692				82.4		52.2		74.5555555555555		85.5			66	70.2222222222222			85.5		70.75		83.5333333333333			
27.076923	17.538461	14.038461	18.576923	56.4	26	25.6	26.6	37.222222	37.333333	37.2	29.05	19.25	66	22.944444	23.666666	23.611111	38.5	47	38.8125	31.9375	24.3	22.166666	21.866666	15.2
1 Function Needs	2 Function Display	3 Multi Pur -poses	4 Flexible Level	5 Ergonom ics	6 Tactile Touching Time	7 Using Difficulty	8 Inter -ference Factors	9 Engage -ment Role	10 User Numbers	11 Sharp Protru -sions	12 Flexible Elements	13 Use Zone Area	14 Noise Assess -ment	15 Natural Lighting Control	16 Artificial Lighting Control	17 View Block	18 Tempera ture Change	19 Humidity Change	20 Sharp Odor	21 Ventila -tion Change	22 Quiet Space	23 Active Space	24 Traffic Area	25 Activity Interrup -tion
8	6	5	7	9	6	8	7	5	4	8	7	5	8	7	6	5	8	8	9	7	9	7	8	6
26				15		15		9		20			8	18			16		16		30			
0.3076923	0.2307692	0.1923076	0.2692307	0.6	0.4	0.5333333	0.4666666	0.5555555	0.4444444	0.4	0.35	0.25	1	0.3888888	0.3333333	0.2777777	0.5	0.5	0.5625	0.4375	0.3	0.2333333	0.2666666	0.2
88	76	73	69	94	65	48	57	67	84	93	83	77	66	59	71	85	77	94	69	73	81	95	82	76

Instruction

Designer Give Score	0’ - 100’
Designer Give Weight	0’ - 10’
Evaluation Final Score	0’ - 100’

Table 3.23 Example of Calculation Table

3.2.3 Final Delivery

After the analysis and concept design, the final step in the design phase will be the final delivery. For final delivery, it will contain two principal portions. The first one will be the documents that designers are required to finish in the preparing phase and the design phase. Like the tables placed before, they will include the interior space research, exterior space research, user research, analysis, weight tables for first and second class indices, weights and scores table for third class index, calculation table, features list and changes list. The second one will be the final representation of space design and a systematic adaptability instruction for clearly explaining the space alternation. It will mainly include the design representation for the different age periods. At most, there will be four plans, indoor elevation, and rendering for the four different age periods.

3.3 Construction Phase

The third phase in the design approach will be the construction phase. It appears when the concept design is finished. Designers need to supervise and give advice to the execution process of the space design. Designers would help the constructors to check the construction documents, which include the joint details, instruction, and budget control. Furthermore, designers would help to manage the construction process, which contains the soft loading selection, soft loading purchase, and construction inspection.

Chapter 4 Design Application

This chapter will explain the specific application of children space design depending on the design approach. The detailed process of space design refers to Figure 3.1. The design application will start from the Preparing Phase, the Design Phase, to the Implementation Phase.

4.1 Preparing Phase

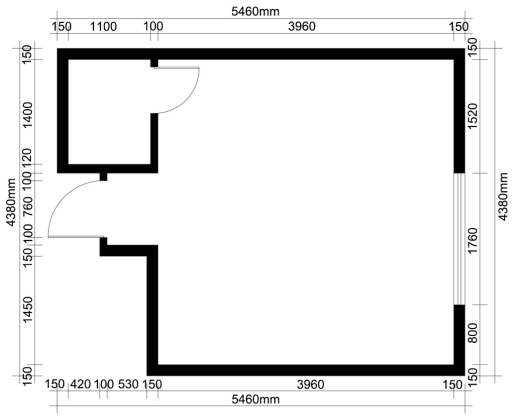
In the very first step, designers need to investigate the children's room and requirements in details. Designers are required to fill the research form and draw the necessary sketches to represent the information from the research. In the chapter of the design application, a room of an apartment which is from Auburn, Alabama, US was chosen to finish the overhaul about the children's growing room. This thesis will carefully examine this room.

4.1.1 Space Research

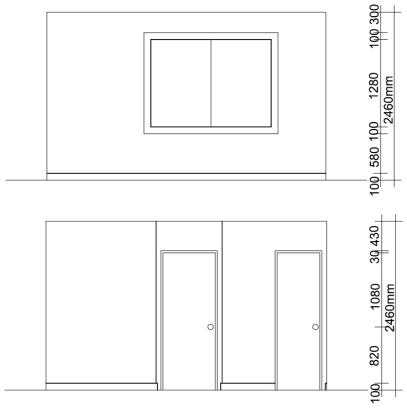
Interior Space Research: At first, designers would investigate the interior circumstance of this room. According to the study, designers could recognize the room type and the roof type. The shape of the room is square. There is also a small walk-in closet on the north-west of the room. The main door is placed in the middle of the west wall, which is 4380mm. Also, the window is located in the middle of the east wall, which is also 4380mm. The walls on the north and south, length is 3960mm, have no doors and windows on them. The height of the room is 2460mm. Because of the direction of windows, the room would only have sunlight in the morning during different seasons. The room would be under the shade in the noon and afternoon. The direct sunlight would move from the middle to the south and move back from the south to the north of the room in different seasons. The wind direction is from the west to the east.

Interior Space Research

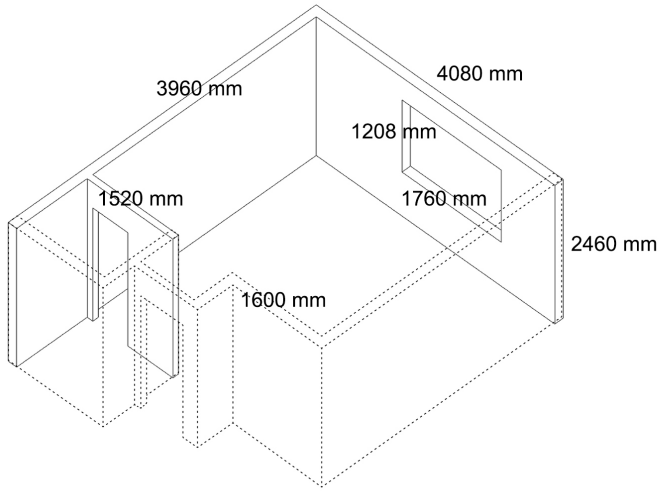
House Type	Room Size Information		
☑ Apartment / ☐ House ☑ Flat Roof / ☐ Pitched Roof	Area: 21.4 ㎡ Length: 5460 mm Width: 4380 mm Height: 2460 mm	Door Location: west/middle Door Scale: 760x2200 mm Door Quantity: 1	Window Location: east/middle Window Scale: 1760x1280 mm Window Quantity: 1



PLAN



ELEVATION



ISOMETRIC VIEW

1

Table 4.1 Interior Space Research 1

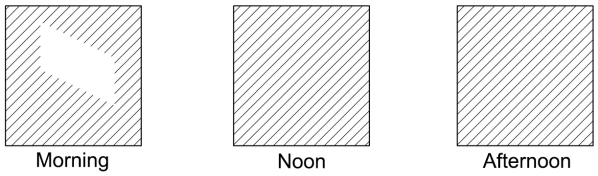
Interior Space Research

Natural Light

Site: Auburn, AL, US, facing to east

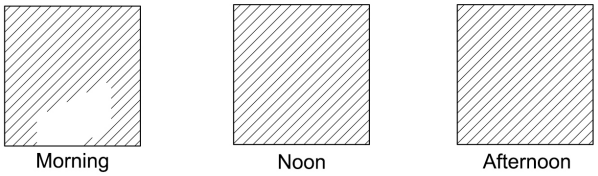
Glass Transparency: 100%

Spring



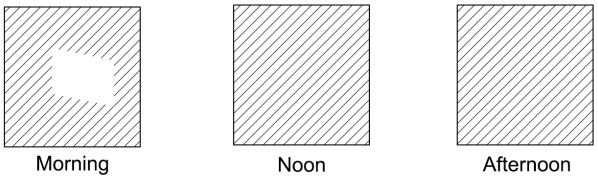
PLAN

Summer



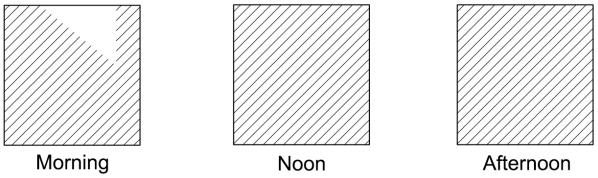
PLAN

Autumn



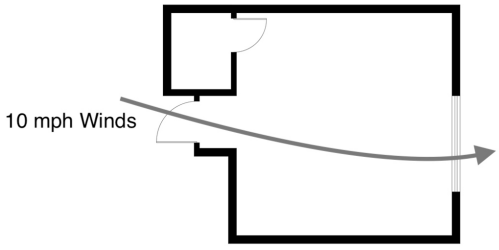
PLAN

Winter



PLAN

Ventilation and Circulation



2

Table 4.2 Interior Space Research 2

Exterior Space Research

House Construction	Wood Frame	
Outside Environment	Virescence	Distance: 0 mile
		Quantity: /
		Type: Lawn, Tulip Poplar
	Roads	Distance: 0.1 mile
		Type: Avenue
	Neighborhood Distance	Distance: 0 mile
		Type: Student Apartment
Noise Assessment	50 dB, Silence Zone	
3		

Table 4.3 Exterior Space Research

Exterior Space Research: To better design the children room, designers also need to investigate the outside environment. According to the study, the road and neighborhood have a distance away from the children's room. Therefore, the location of the apartment is relatively quiet. Virescence maintains well. There is a large area of lawn outside the apartment. Also, no trees outside the room window blocks the sunlight and wind entering the room.

4.1.2 Space Research Analysis

According to the low height, flat roof, and relatively small area, the room is not suitable to be divided into small space spaces horizontally and vertically. Also, the orientation of the room determines that the daylighting is inadequate. Therefore, designers need to use a light color, which could visually enlarge the whole space and reflect more lighting in the day time. The separate small walk-in closet brings more opportunity for storage. Designers need to take full advantage of this small space so that the central open space would be more clean and organized. Because of the deficient natural lighting, designers should add more artificial lighting for children to meet the brightness demand at noon and in the afternoon. Fortunately, there is no tree outside the window to block the insufficient natural lights. Also, the area is quiet, so that the room does not need additional acoustic treatment.

4.1.3 User Research

Besides the interior space research and exterior space research, designers are also required to finish examining the requirement of the users. Designers need to use the user research tables to study the necessary information of the children and the specific demands of parents and children. The tables should be finished by both parents and children. The parents need to write down their wishes for their expecting children's room if their child is not born.

Basic Information of User: The study of necessary information of the user includes the age division options, children's age, and gender, children's living habit, interests, and the expecting style. According to the study, the parents select the beginning age period of age zero to three and the ending age period of age twelve to eighteen. They would like the children's room could grow with the children from age zero to eighteen. Therefore, there will be four space designs during different age periods and three big changes during that time. Designers need to design the first space for age zero to three, the second space for age three to six, the third space for age six to twelve, and the fourth space for age twelve to eighteen. As for the children's living habit and their interests, parents could keep it blank if they cannot provide the information. Finally, the parents expect that the children room's design is playful and has a simple Scandinavian style.

Specific Demands of User: This table will be completed based on the information of the basic information of the user research table. Because the parents select four age periods for the adaptability of children's room, they would fill in four tables corresponding to the four age periods. In each table, parents need to write down the physical features of their children, the expectant function zones, the pain points, and the desired abilities and needs in different development aspects. Depending on this case, since there is no information about the physical features of the children, designers need to appoint the general physical details for reference. According to the tables, parents select different function zones, pain points, and abilities in the different four age periods. Designers need to analyze these demands carefully. Finding their relationship could help to create the adaptability of the room. This part of analysis will be shown in the next section.

User Research 1

Name: User 1 Age: Unborn Gender: Unknown		
Children Age Selection		
Selection	Beginning Age Period	Ending Age Period
☐	Age 0-3	Age 3/6
☐	Age 0-3	Age 6/12
☑	Age 0-3	Age 12/18
☐	Age 3/6	Age 6/12
☐	Age 3/6	Age 12/18
☐	Age 6/12	Age 12/18
Living Habit	Interest	Style Preference
Unknown	Unknown	Simple, Scandinavian
1		

Table 4.4 User Research 1

User Research 2_Age 0-3

Basic Information	**Name:** __User 1__ **Gender:** __Unknown__	
Physical Features (cm, kg)	**Length:** __50 - 95__ **Weight:** __3.5 - 14__ **Shoulder:** __16 - 24__ **Arms Span:** __15 - 97__ **Vertical Reach to Grip:** __76 - 106__ **Seated Eye Level:** __42 - 44__ **Standing Eye Level:** __x - 76__	
Function	Sleeping Area / Playing Area / Storage Area for adults	
Pain Points	Safety / Intelligence / Curiosity	
	Ability / Need	**Analysis**
Motor Development	**Roll / Sit / Crawl** ☑	
	Stand / Walk ☑	
	Walk up / down stairs ☐	
	Run ☐	
	Climb ☑	
	Jump ☑	
	Throw ☐	
	Ride ☐	
Perceptual Development	**Touch Stimulation** ☐	
	Hearing Stimulation ☑	
	Vision Stimulation ☑	
Social Emotional Development	**Self-emotional expression** ☑	
	Self-conscious expression ☑	
	Self-evaluation regulation ☑	
Cognitive Development	**Imitation of behaviors** ☐	
	Understanding of objects ☐	
	Awareness of categorization ☑	
2		

Table 4.5 User Research 2_Age 0 to 3

User Research 2_Age 3-6

Basic Information	**Name:** __User 1__ **Gender:** __Unknown__	
Physical Features (cm, kg)	**Height:** __95 - 115__ **Weight:** __14 - 20__ **Shoulder:** __24 - 28__ **Arms Span:** __97 - 115__ **Vertical Reach to Grip:** __106 - 137__ **Seated Eye Level:** __44 - 54__ **Standing Eye Level:** __76 - 106__	
Function	Sleeping Area / Playing Area / Storage Area for children / Studying Area	
Pain Points	Storage / Interest Cultivation / Exploration	
	Ability / Need	**Analysis**
Motor Development	**Walk up / down stairs** ☐	
	Climb ☑	
	Jump ☐	
	Throw ☐	
	Dress ☑	
Social Emotional Development	**Self-emotional regulation** ☑	
	Self-conscious expression ☐	
	Self-esteem establishment ☑	
	Self-control establishment ☑	
Cognitive Development	**Drawing** ☑	
	Understanding of space ☐	
	Complex play ☐	
	Distinguish reality & illusion ☑	
3		

Table 4.6 User Research 2_Age 3 to 6

User Research 2_Age 6-12

Basic Information	**Name:** __User 1___ **Gender:** __Unknown__	
Physical Features (cm, kg)	**Height:** __115 - 150__ **Weight:** __20 - 42__ **Shoulder:** __28 - 36___ **Arms Span:** ___115 - 152___ **Vertical Reach to Grip:** ____137 - 183____ **Seated Eye Level:** ___54 - 66__ **Standing Eye Level:** ___106 - 137__	
Function	Sleeping Area / Studying Area / Storage Area for children / Hobby Area	
Pain Points	Hobby Development / Academic Development / Self-control	
	Ability / Need	**Analysis**
Motor Development	**None**	
Social Emotional Development	**Self-emotional regulation** ☑	
	Personality expression ☑	
	Self-esteem improvement ☑	
	Self-control improvement ☑	
Cognitive Development	**Thinking logically** ☑	
	Understanding of space ☐	
4		

Table 4.7 User Research 2_Age 6 to 12

User Research 2_Age 12-18

Basic Information	**Name:** __User 1___ **Gender:** __Unknown__	
Physical Features (cm, kg)	**Height:** __150 - 165__ **Weight:** __42 - 56__ **Shoulder:** __36 - 43___ **Arms Span:** ___152 - 170___ **Vertical Reach to Grip:** ____183 - 190____ **Seated Eye Level:** ___66 - 78__ **Standing Eye Level:** ___137 - 158__	
Function	Sleeping Area / Studying Area / Storage Area for adults	
Pain Points	Personality / Privacy / Independence / Mental Health	
	Ability / Need	**Analysis**
Motor Development	**None**	
Social Emotional Development	**Personality expression** ☑	
	Self-esteem improvement ☑	
	Self-control improvement ☑	
Cognitive Development	**Propositional thought** ☐	
	Display imaginary audience ☐	
5		

Table 4.8 User Research 2_Age 12 to 18

In this case, parents have selected the beginning age period of age 0 to 3, and the ending age period of age 12 to 18. The parents would like to prepare their soon-to-be-born baby a room from age 0 to 18 years old. Designers need to consider the room design and the adaptability for four main age periods. As for the selection of functional zones, parents have chosen the sleeping area, playing area, and storage area for the age 0 to 3. They would add the studying area in the age 3 to 6, and prepare the storage area for children. When the children go to school, they will change the playing area to hobby area. It is a challenge for designers to organize these functional zones in limited space and design the adaptability between the two age periods.

These zones might overlap with others. The baby is unborn so that parents could not provide precise information about the gender, living habit, and interest of the child. However, for the pain points, parents could offer their concerns and expectation for their child.

Depending on the study, the pain points in different age periods are Safety, Storage, Interest Development, and Personality and Privacy. Designers should reserve enough open space in the space design for age 0 to 3 so that the room could be malleable and designed to be changed in the future. The removable furniture and equipment is the priority. Then, the storage space should have the proper height. Thus children could easily reach the storage space. It will be better for children to cultivate a good habit of storage. In the age span of 12 to 18, designers should leave a space for children as an interest utility space. With children enter adolescence, designers should prepare a space which is blank and private. Thus children could use their imagination to overhaul and decorate their space by themselves to show their personality.

4.1.4 User Research Analysis

According to the unknown gender, broad age range, and style preference, creating a neutral spatial style will be suitable for different genders and age periods. Also, the function areas vary with age. Thus, designers might keep some function space, like sleeping area and storage area, unmovable and leave a fraction of the area, like storage area and study area, changeable. The data of physical features might be a reference for designers to create prefabricated equipment.

The age 0 to 3 is the essential period for infants to develop some basic abilities. Also, there are the most numerous ability options in this period. However, the abilities that could be improved directly by the space design is limited. Considering about the spatial extension in the future, designers might to leave enough open space in the beginning of the design. This kind of open space will also help children learn to roll, sit, crawl, stand and walk. It might provide children the opportunity to explore the world. The need for children to climb and jump are required only from age 0 to 6, hence, the function of the equipment for climbing and jumping might be changed to other functions that could be used to meet the other demands for the adolescents.

Except for the motor development, children's need for social emotional development and cognitive development are concerns from age 0 to 18. It is hard to design a furniture or equipment that fit children's need in these aspects, but designers could achieve the improvement in social emotional development and cognitive development through meeting children's other needs.

User Research 2_Age 0-3

Basic Information	**Name:** __User 1___ **Gender:** __Unknown__	
Physical Features (cm, kg)	**Length:** __50 - 95__ **Weight:** __3.5 - 14__ **Shoulder:** __16 - 24___ **Arms Span:** ___15 - 97___ **Vertical Reach to Grip:** ____76 - 106____ **Seated Eye Level:** ___42 - 44___ **Standing Eye Level:** ___x - 76___	
Function	Sleeping Area / Playing Area / Storage Area for adults	
Pain Points	Safety / Intelligence / Curiosity	
	Ability / Need	**Analysis**
Motor Development	**Roll / Sit / Crawl** ☑	Open space: activity space reserve for future space extension
	Stand / Walk ☑	Main area: sleeping area playing area
	Walk up / down stairs ☐	
	Run ☐	
	Climb ☑	Combine with other function / furniture Flexible and removable (furniture)
	Jump ☑	
	Throw ☐	
	Ride ☐	
Perceptual Development	**Touch Stimulation** ☐	
	Hearing Stimulation ☑	Noise reduction Distinguish active area and quiet area
	Vision Stimulation ☑	Proper spacial circumstance (color and material of the floor, wall and ceiling)
Social Emotional Development	**Self-emotional expression** ☑	
	Self-conscious expression ☑	Creative activity space
	Self-evaluation regulation ☑	Easy achievement High evaluation Proper storage system (cultivate good habit)
Cognitive Development	**Imitation of behaviors** ☐	
	Understanding of objects ☐	
	Awareness of categorization ☑	Low height storage system One categorized approach
	2	

Table 4.9 User Research 2_Analysis 1

User Research 2_Age 3-6

Basic Information	**Name:** __User 1__ **Gender:** __Unknown__	
Physical Features (cm, kg)	**Height:** __95 - 115__ **Weight:** __14 - 20__ **Shoulder:** __24 - 28__ **Arms Span:** __97 - 115__ **Vertical Reach to Grip:** __106 - 137__ **Seated Eye Level:** __44 - 54__ **Standing Eye Level:** __76 - 106__	
Function	Sleeping Area / Playing Area / Storage Area for children / Studying Area	
Pain Points	Storage / Interest Cultivation / Exploration	
	Ability / Need	**Analysis**
Motor Development	**Walk up / down stairs** ☐	Main area: sleeping area playing area Low height storage system Two categorized approach
	Climb ☑	
	Jump ☐	
	Throw ☐	
	Dress ☑	Combine with other function / furniture Flexible and removable (furniture)
Social Emotional Development	**Self-emotional regulation** ☑	Proper spacial circumstance (color and material of the floor, wall and ceiling)
	Self-conscious expression ☑	
	Self-esteem establishment ☑	Easy achievement High evaluation
	Self-control establishment ☑	Proper storage system (cultivate good habit)
Cognitive Development	**Drawing** ☑	Creative activity space
	Understanding of space ☐	
	Complex play ☑	
	Distinguish reality & illusion ☐	
3		

Table 4.10 User Research 2_Analysis 2

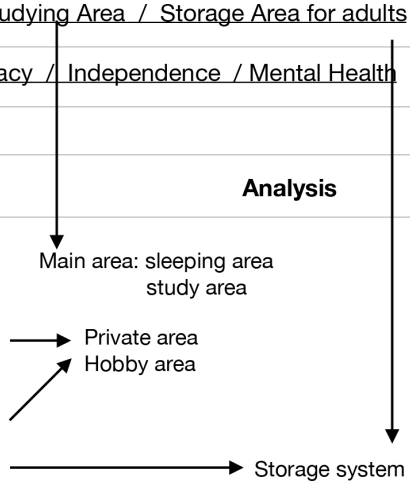
User Research 2_Age 6-12

Basic Information	**Name:** __User 1___ **Gender:** __Unknown__	
Physical Features (cm, kg)	**Height:** __115 - 150__ **Weight:** __20 - 42__ **Shoulder:** __28 - 36___ **Arms Span:** ___115 - 152___ **Vertical Reach to Grip:** ____137 - 183____ **Seated Eye Level:** ___54 - 66__ **Standing Eye Level:** ___106 - 137__	
Function	Sleeping Area / Studying Area / Storage Area for children / Hobby Area	
Pain Points	Hobby Development / Academic Development / Self-control	
	Ability / Need	**Analysis**
Motor Development	**None**	Main area: sleeping area study area Low height storage system Complex categorization
Social Emotional Development	**Self-emotional regulation** ☑	Proper spacial circumstance (color and material of the floor, wall and ceiling) Private area
	Personality expression ☑	
	Self-esteem improvement ☑	
	Self-control improvement ☑	
Cognitive Development	**Thinking logically** ☐	
	Understanding of space ☑	Distinguish active area and quiet area
4		

Table 4.11 User Research 2_Analysis 3

User Research 2_Age 12-18

Basic Information	**Name:** __User 1___ **Gender:** __Unknown__	
Physical Features (cm, kg)	**Height:** __150 - 165__ **Weight:** __42 - 56_ **Shoulder:** __36 - 43___ **Arms Span:** ___152 - 170___ **Vertical Reach to Grip:** ____183 - 190____ **Seated Eye Level:** ___66 - 78__ **Standing Eye Level:** ___137 - 158__	
Function	Sleeping Area / Studying Area / Storage Area for adults	
Pain Points	Personality / Privacy / Independence / Mental Health	
	Ability / Need	**Analysis**
Motor Development	**None**	
Social Emotional Development	**Personality expression** ☑	
	Self-esteem improvement ☑	
	Self-control improvement ☑	
Cognitive Development	**Propositional thought** ☐	
	Display imaginary audience ☐	



5

Table 4.12 User Research 2_Analysis 4

4.2 Design Phase

In the second phase of the design approach, designers need to analyze the results of the research carefully, and then designers should do the concept design about the space arrangement, furniture selection, equipment creation, and the adaptability design. After the concept design, designers need to evaluate the different options of concept design. Users need to select their favorite concept according to the conclusion of the evaluation. Finally, designers are required to produce the design representation as the final delivery.

4.2.1 Concept Generation

The first step in the design phase is the concept generation. First, designers need to consider the arrangement of function zones in the whole space. Then, designers need to set up the overall style of the space, which is influenced by the color and material of the wall, floor, and ceiling. Next, designers are required to create some equipment or prefabrication system to fit more children's requirements. Last, some furniture and decoration are selected and settled to the space to demonstrate the utility in the specific space.

4.2.1.1 Space Arrangement

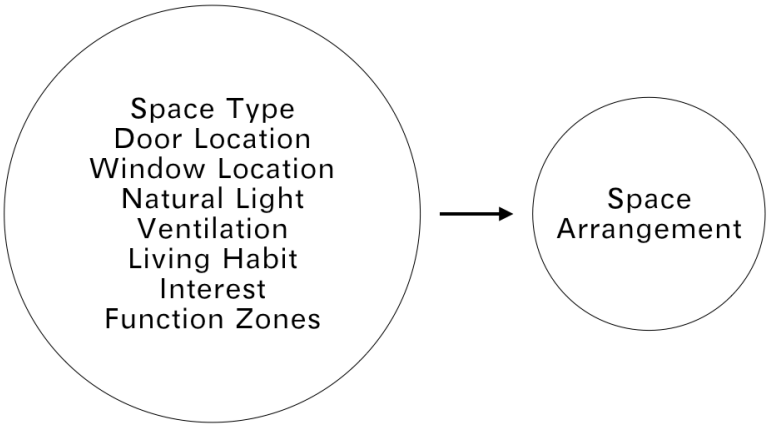


Figure 4.1 Space Arrangement Influence Factors

As the research displayed before, several factors might affect the arrangement of the space. Designers need to examine the functional zones in one age period and the adaptability in the other age periods in the meantime. In this case, first, designers would split the room into the main two areas, which are the privacy zone and the activity zone. The privacy zone on the left part of the room could have relatively less standard sunshine time and lower noise. Also, the activity zone near the window could hold long hours of daylight. The clear separation of the two primary functional zones could reduce the interference between diverse activities.

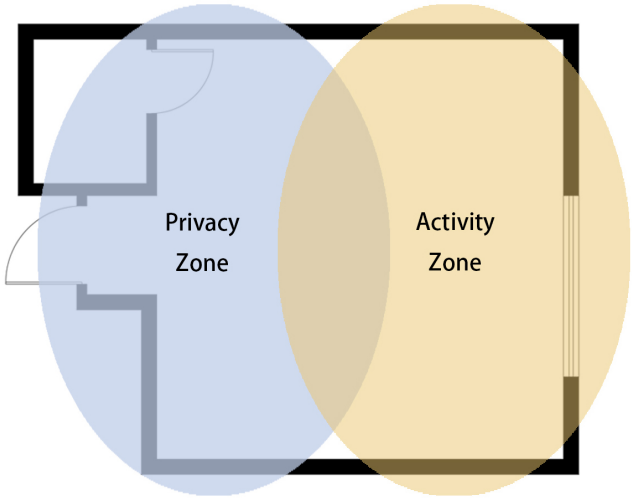


Figure 4.2 Privacy Zone and Activity Zone

Then, designers considered the specific separation areas inside the two primary zones. Depending on the demands of children and parents in the user research, designers managed the storage area and the sleeping area in the privacy zone and confirmed these areas would be relatively stationary in the future adaptability. In the contrast, the play area and study area were placed on the activity zone. Also, these areas were flexible and would alter their location for adaptability.

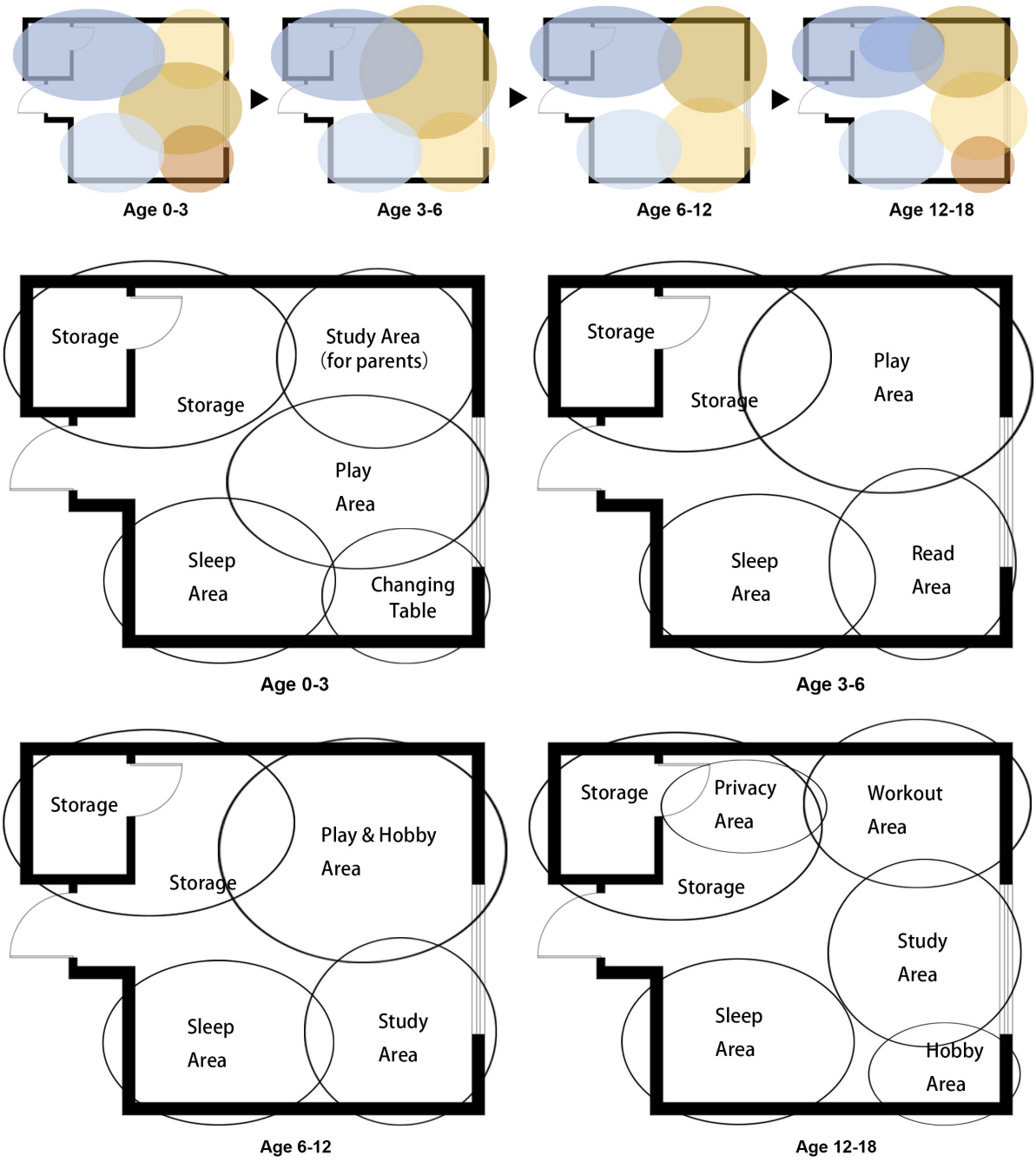


Figure 4.3 Arrangement of Functional Areas

The area in front of the window was prepared for the essential activity in every age period. For the age of 0 to 3, children would learn to sit, crawl, stand, and walk. Thus, the play area was the main activity and settled in front of the window. Similarly, the play area moved upward to the right corner slightly and shared more space for study and reading area when children got older. When children entered the age 12, at which time it is suggested that they would spend more time in front of the table, the study area finally occupied the most area of the activity zone and filled the place in front of the window.

4.2.1.2 Environment Consideration

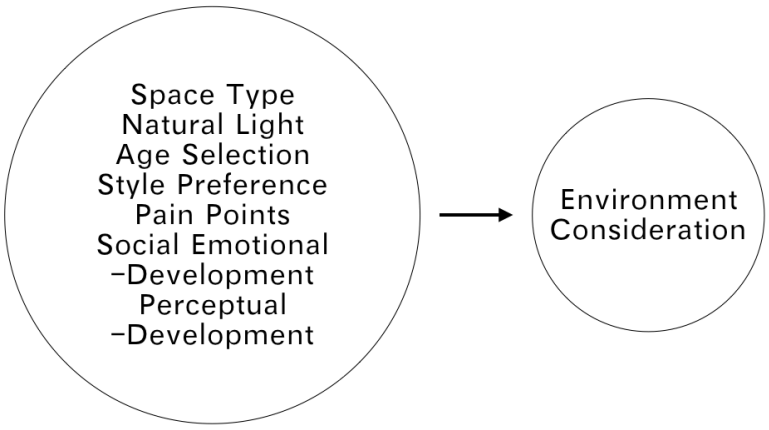


Figure 4.4 Environment Consideration Influence Factors

After the completion of the fundamental space arrangement, designers started to recognize the indoor atmosphere, which was affected by the material, texture, and color of the wall, floor, and ceiling in the room. The scheme of the interior atmosphere should fit the children from age 0 to 18.

To better accomplish the user's demand, the user selected four existing interior design corresponding to the four age ranges for the environment inspiration. Depending on the user

research, the designer could understand that the user wanted their room to be a modern, simple, and universal design style. They also expressed the favor of wood and Norwegian design style.

Age 0-3

Age 3-6

Age 6-12

Age 12-18

Figure 4.5 Environment Consideration_Examples

The size of the room and sunlight are limited. The application of light color would visually expand the space, so designers selected the light and cool color wood for the primary material, and determined the light gray for the main color. The tone of the color in the room would convey an atmosphere of natural, cool, and calm. Designers listed six options of the arrangement of the material and color to examine the possibility.

Option / Function	Wall	Floor	Ceiling
1	Wood	Light Gray	Light Gray
2	Light Gray	Wood	Light Gray
3	Light Gray	Light Gray	Wood
4	Wood	Wood	Light Gray
5	Wood	Light Gray	Wood
6	Light Gray	Wood	Wood

Table 4.13 Material and Color Options

4.2.1.3 Prefabrication Creation

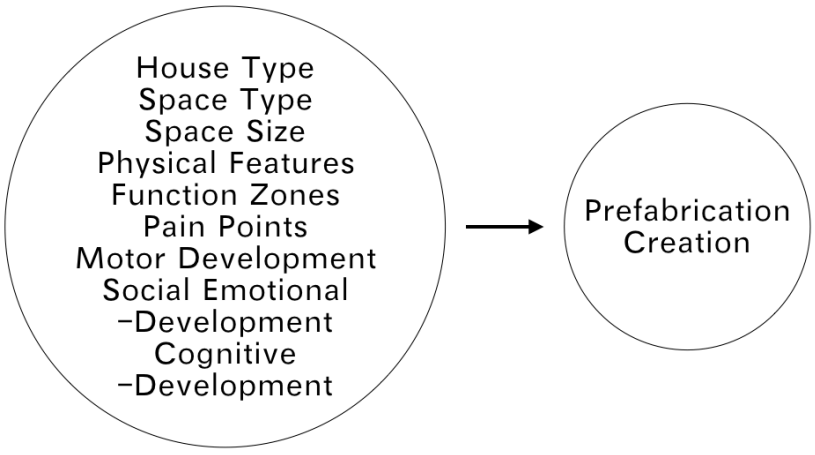


Figure 4.6 Prefabrication Creation Influence Factors

In this case, the walk-in closet is relatively isolated. According to the research, the L-shape wall that encircles the closet is not the load-bearing wall. To expand the available space in the room, the designer removed the L-shape wall and added a new L-shape prefabricated bookshelf on the right of the walk-in closet. Thus, the walk-in closet was opened and infused into the main space in the bedroom. The storage area was enlarged. Also, the function of the new space inside the storage area became more flexible. The following space organization was produced in the new place.

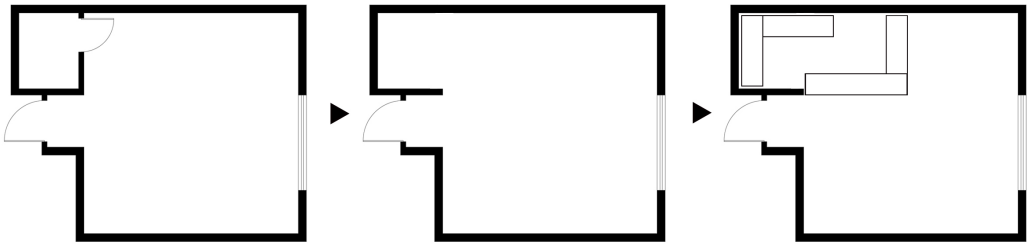


Figure 4.7 Prefabricated New Space

The first prefabricated system is the storage system. It should have the ability to store clothes, books, toys, and all the other items. Clothes could be located in the cabinet in the corner. Books could be displayed on the L-shape shelf. Also, the small items could be directly performed on the shelf, or be collected into different drawers or boxes which could be placed on the shelf. The storage place should have different heights, so it would be easy for children to practice the ability of storage and categorization. A simple grid shelf is suited for all demands from age 0 to 18.

Then, the second prefabricated system is the table system. When children get older, they would need a larger table surface and higher height to meet their growing body. According to the

diverse space arrangement, designers set three distinct table surfaces and heights. This system was attached on the wall with the window. Children could disassemble the legs and hold the tables when they need it and put it down when they do not need it.

Next, the third prefabricated system is the climbing frame. It was placed inside the grid bookshelf. Also, the climbing frame could be disassembled and moved for different requirements. It could be the climbing frame, slippery frame, clothing rack and stretch frame.

The fourth prefabricated system is the blackboard wall. Children could draw on it.

The fifth prefabricated system is the hanging system. It could be used as the swing or the horizontal bar.

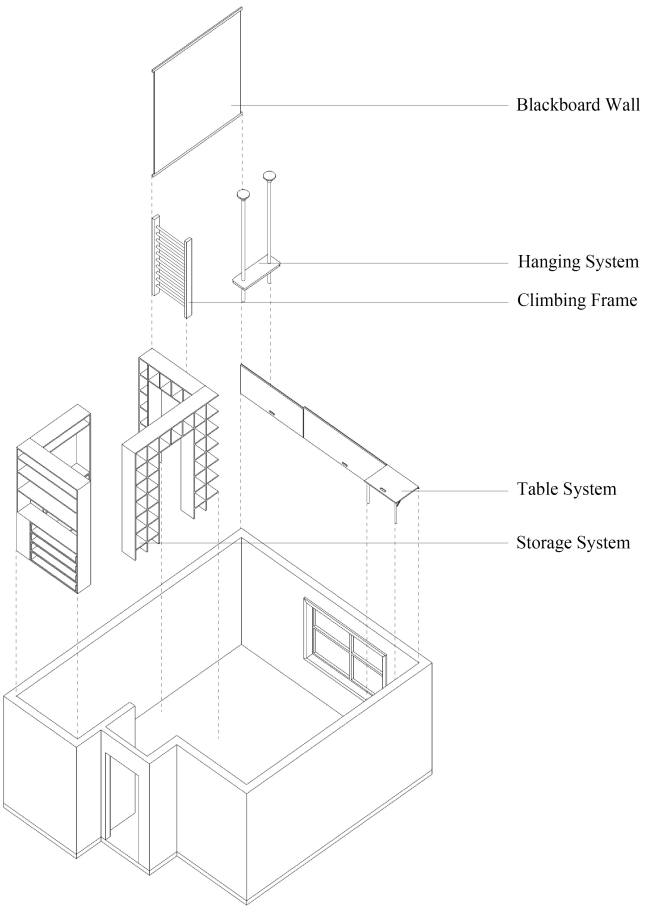


Figure 4.8 Prefabricated Systems

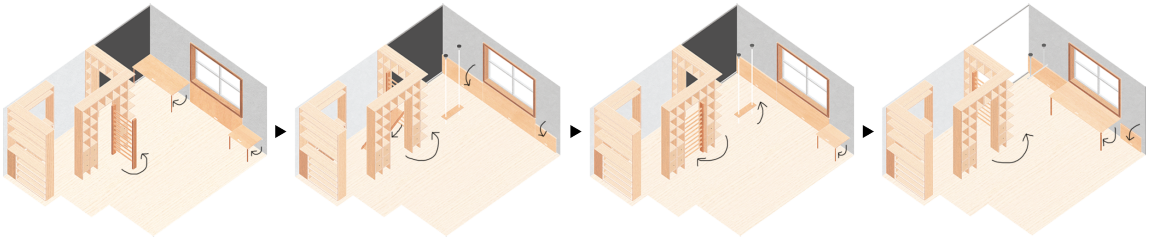


Figure 4.9 Prefabricated Systems Variation

After designers determine the prefabricated systems, they need to look back to the environmental consideration. For a better visual experience, designers choose the wood as the floor material, and the gray concrete as the wall and ceiling material. The prefabricated systems would all use the light color wood that coordinates with the floor color. Then, for the ultimate adaptability of these prefabricated systems, the storage system and the blackboard wall would keep stationary from age 0 to 18. The climbing frame, table system, and hanging system would move to meet different requirements.

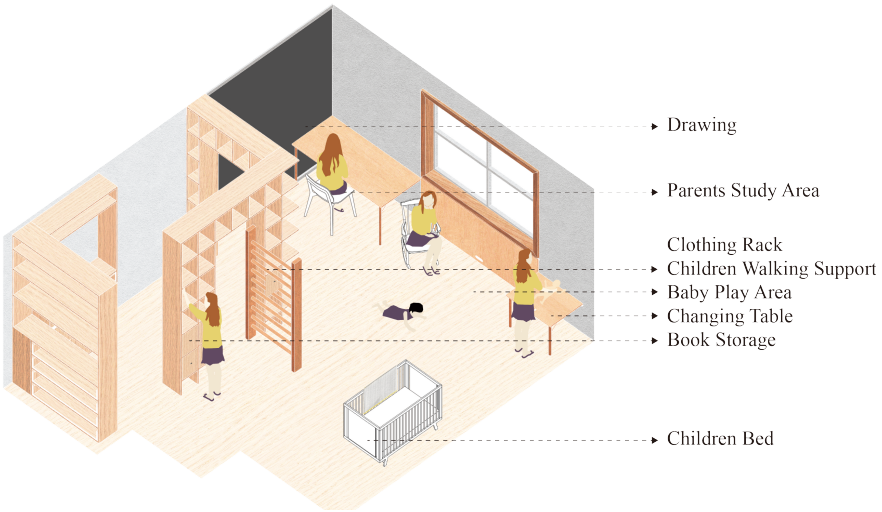


Figure 4.10 Children Room Function Age 0 to 3

As the illustration represented above, baby in age 0 to 3 might not use the full space. They begin to develop the awareness of categorization, but their immature motor ability could not support them to store items by themselves. Hence, the storage system and table system are mainly utilized for parents. Parents would apply the larger table for study and the smaller table for changing baby's clothes. Then, the play area for baby is wide and flat. Thus they could freely practice to roll, sit and crawl. The climbing frame could encourage baby to hold it in order to walk and climb.

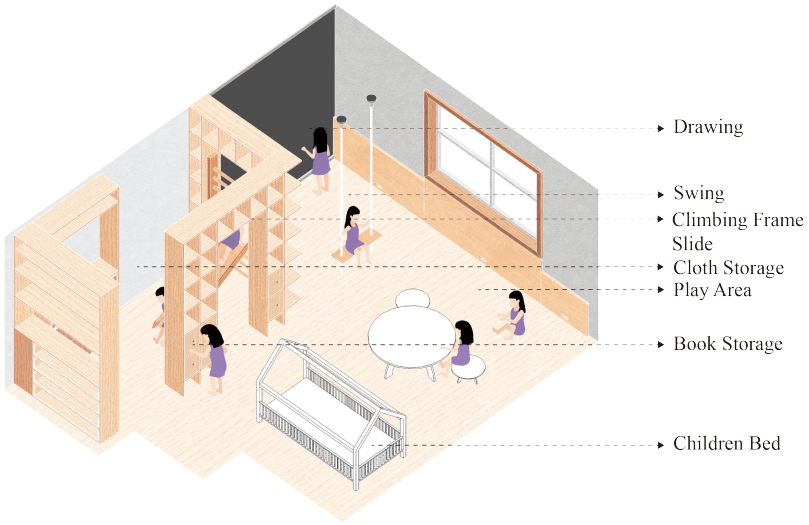


Figure 4.11 Children Room Function Age 3 to 6

When children enter the stage of preschool, they would entirely own their room. The request for play is crucial for children in this stage. They rise to explore the world by themselves. The storage system plays a vital role in this period. Children could use the lower part of the cabinet and the bookshelf to learn to collect clothes and toys, even though they could only be aware of one categorization. The blackboard wall offers children the freedom to express their self-consciousness. The broad play area could accommodate more massive imitation toys, which

provide children the opportunity to study complex play. The climbing frame, children slide and swing not only encourage children to improve their motor skills but also assist them to establish their self-esteem.

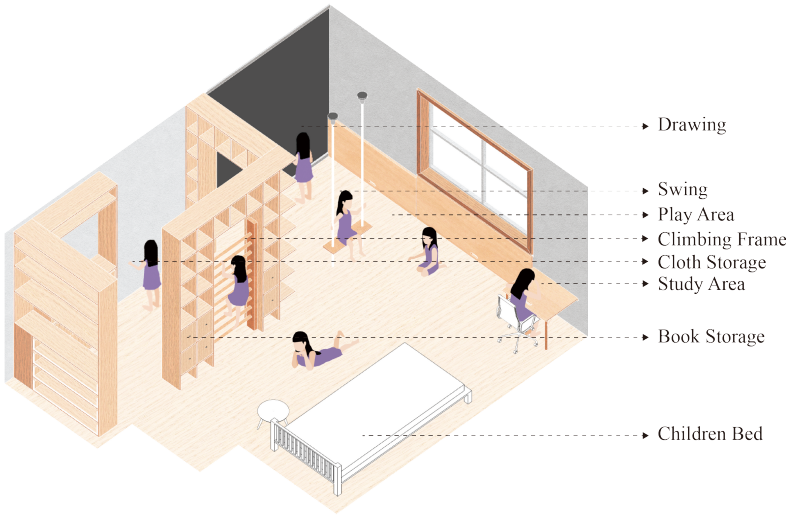


Figure 4.12 Children Room Function Age 6 to 12

On the last period, playing is the primary theme of the room. Play area invades the storage system and study area. Unlike the last stage, in this period, the play area, study area and storage area equally divide the space. Children would learn to recognize more categorizations of the clothes, toys, and books. The slide is removed, but the climbing frame, swing and blackboard wall are kept. The changing table is used as kid's studying table, because it has the proper height for elementary students.

For adolescent whose age is between 12 to 18, the study load grows heavy over time. Hence, the study area increasingly shifts to the primary theme of the room. The table in front of the window affords sufficient broad surface and proper height. Grid bookshelf offers enough space to stock different books. It could also be a display space for children to display their

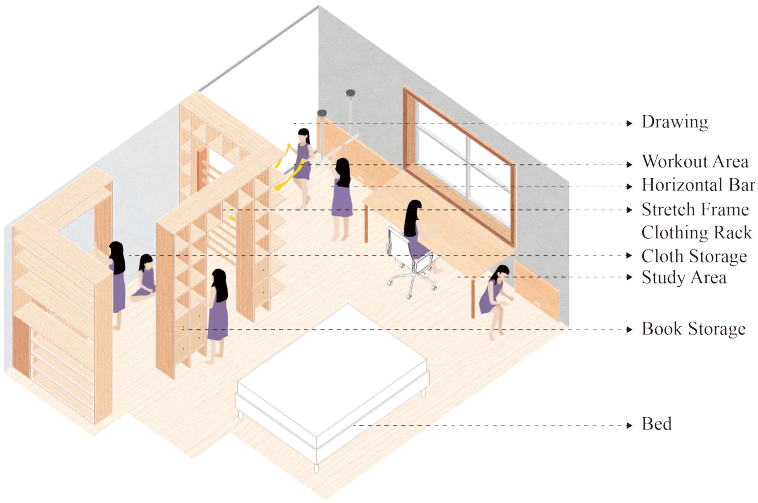


Figure 4.13 Children Room Function Age 12 to 18

diverse works. The play area is transformed into the workout area. As the picture showed above, the hanging system is utilized as a horizontal bar or flying rings. Also, the stretch frame and clothing rack are adapted from the old climbing frame. Adolescents might experience low self-esteem in this stage. Thus, the place inside the storage area provides a private and isolated field for them to possess the feeling of security.

4.2.1.4 Furniture Selection

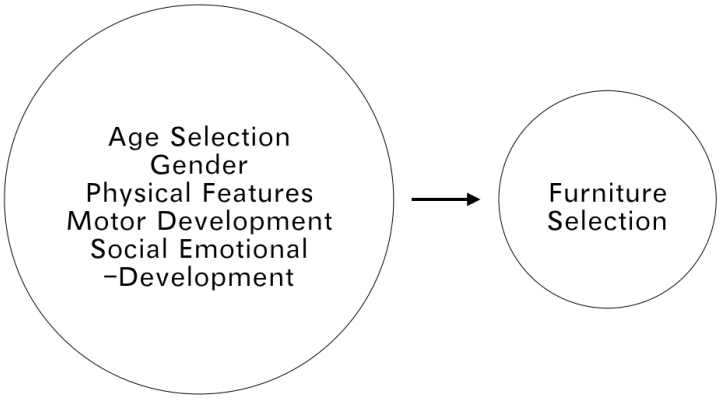


Figure 4.14 Furniture Selection Influence Factors

As the design approach described, designers are required to simulate the final space situation with furniture to prove the usability of the space design. Designers also could advise parents about the selection of furniture. In this case, the light wood color and light gray bring a neutral atmosphere. Thus, the furniture in different style and form would merge with space and interact with space. Designers could use the way of collage to express their advise and idea.

Figure 4.15 Furniture Selection Children Room Age 0 to 3

Figure 4.16 Furniture Selection Children Room Age 3 to 6

Figure 4.17 Furniture Selection Children Room Age 6 to 12

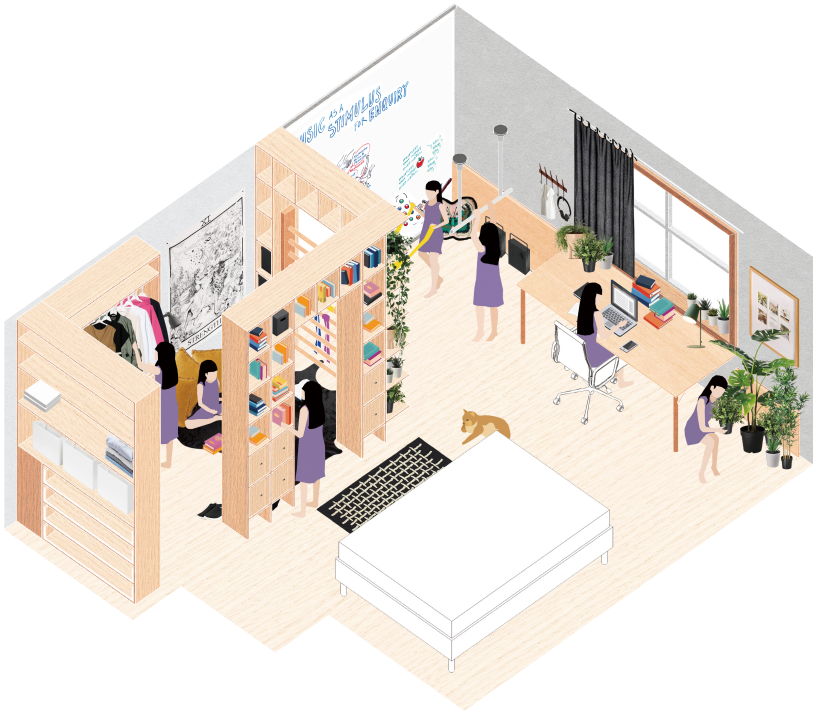


Figure 4.18 Furniture Selection Children Room Age 12 to 18

4.2.2 Evaluation

The evaluation will happen when the design has been finished. When designers have more than two concepts, they need to use the evaluation approach to calculate the final score of each design. The final score could be the reference for users to make their final decision of selecting the concept. However, it will not be the only reference standard.

In this case, designers need to provide weight and scores for the various indexes and fill two forms, which include all indexes. First, designers give weights, which is from 0 to 10 for the first class and second class indices to express their differing importance. The details of the

Table of Weights

Weight Table_First Class Index				
Indicators	1 Design Usability	2 Spatial Influences	3 Aesthetic Factors	4 Environmental Considerations
Weight	9	7	8	6

Weight Table _ Second Class Index_Design Usability					
Indicators	1 Function Solution	2 Using Comfort Level	3 Interactive Level	4 Users Engagement	5 Safety Level
Weight	9	7	8	9	6

Weight Table _ Second Class Index_Spatial Influences					
Indicators	6 Acoustic Environment	7 Luminous Environment	8 Thermal Environment	9 Air Quality	10 Space Arrangement
Weight	8	8	7	9	9

Weight Table _ Second Class Index_Aesthetic Factors			
Indicators	11 Color	12 Form	13 Styling
Weight	8	7	6

Weight Table _ Second Class Index_Environmental Considerations				
Indicators	14 Material Durability	15 Material Environmental Protection	16 Service	17 Cost
Weight	9	7	8	6

1

Table 4.14 Table of Weights

weights are showed below. In this step, designers prove that Design Usability is most important. They also pay more attention to Aesthetic Factors. Spatial Influences are taken into account as well, but they relatively are not concerned about Environmental Considerations.

Second, designers need to give weights and scores to the third class indices in the meanwhile. The scores would closely relate to the design itself. The scores' range is from 0 to 100.

Using the Function Solution as an example, designers give scores by analyzing their design. The prefabricated system provides the proper solution for the user's pain points. Most of the demands of users are solved. Depending on the satisfaction of users, designers could write down a score of 90 for Function Needs. Then, the function of each of the room design is clear and comprehensible for children. Designers could give a score of 88 for Function Display. Next, the storage system, hanging system, climbing frame, and table system are all multi purposes, but the blackboard wall has only one purpose. According to the shortcoming, designers might give a lower score, which is 84 for Multi Purposes. Finally, as for flexibility, the climbing frame could be moved and disassembled. Both of the hanging system and table system have some parts that could be changed. However, the storage system is relatively stationary and inflexible. In conclusion, comparing to the other indexes, the Flexible Level would have the lowest score, which is 70.

The process of giving scores is subjective. Thus the score could be extremely high or low. Designers could give 100 for the design that he or she thinks it is excellent, and give zero for the design that he or she thinks it is terrible. Each of the scores would all work on the final score. According to Chapter Four, designers could use the existing Excel form to calculate the final

Table of Weights and Scores

	Weight Table _ Third Class Index												
Indicators	1 Function Solution				2 Using Comfort Level		3 Interactive Level		4 Users Engagement		5 Safety Level		
Indicators	1 Function Needs	2 Function Display	.3 Multi Purposes	4 Flexible Level	5 Ergonomics	6 Tactile Touching Time	7 Using Difficulty	8 Interference Factors	9 Engagement Role	10 User Numbers	11 Sharp Protrusions	12 Flexible Elements	13 Use Zone Area
Weight	9	6	8	7	9	7	8	6	8	7	9	7	8
Score	90	88	84	70	92	86	87	76	74	65	79	90	83

	Weight Table _ Third Class Index											
Indicators	6 Acoustic Environment	7 Luminous Environment			8 Thermal Environment		9 Air Quality		10 Space Arrangement			
Indicators	14 Noise Assessment	15 Natural Lighting Control	16 Artificial Lighting Control	17 View Block	18 Temperature Change	19 Humidity Change	20 Sharp Odor	21 Ventilation Change	22 Quiet Space	23 Active Space	24 Traffic Area	25 Activity Interruption
Weight	8	9	8	7	8	8	9	7	7	9	7	8
Score	85	79	70	82	81	77	74	69	85	88	89	94

	Weight Table _ Third Class Index								
Indicators	11 Color			12 Form			13 Styling		
Indicators	26 Color Usage	27 Color Matching	28 Emotional Expression	29 Proportion	30 Atmosphere Creation	31 Emotional Experience	32 Wholeness	33 Individuation	34 Detail Completeness
Weight	7	8	7	7	8	8	9	8	6
Score	87	91	90	80	86	79	83	75	68

	Weight Table _ Third Class Index								
Indicators	14 Material Durability			15 Material Environmental Protection			16 Service		17 Cost
Indicators	35 Abrasion Resistance	36 Corrosion Resistance	37 Stability	38 Disposal Difficulty	39 Regeneration Difficulty	40 Repetition Usage Rate	41 Cleaning Difficulty	42 Maintenance Difficulty	43 Cost
Weight	7	8	9	7	5	6	9	8	7
Score	91	84	86	67	71	74	90	82	80

2

Table 4.15 Table of Weights and Scores

score which is 81.55. The table of scores and the Excel form are listed below.

22.1621933621934									16.2941230936819								
3 Aesthetic Factors									4 Environmental Considerations								
8									6								
0.266666666666667									0.2								
83.1082251082252									81.4706154684096								
34.0606060606061			27.2463768115942			21.8012422360249			26.0375			16.437037037037			22.9960784313726		16
Color			Form			Styling			Material Durability			Material Environmental Protection			Service		Cost
8			7			6			9			7			8		6
21									30								
0.380952380952381			0.333333333333333			0.285714285714286			0.3			0.233333333333333			0.266666666666667		0.2
89.4090909090909			81.7391304347827			76.304347826087			86.7916666666667			70.4444444444444			86.2352941176471		80
27.681818	33.090909	28.636363	24.347826	29.913043	27.478260	32.478260	26.086956	17.739130	26.541666	28	32.25	26.055555	19.722222	24.666666	47.647058	38.588235	80
26 Color Usage	27 Color Match -ing	28 Emo -tional Expres -sion	29 Propor -tion	30 Atmos -phere Creation	31 Emo -tional Experi -ence	32 Whole -ness	33 Individua -tion	34 Detail Comple -teness	35 Abrasion Resis -tance	36 Corro -sion Resis -tance	37 Stability	38 Disposal Difficulty	39 Regene -ration Difficulty	40 Repeti -tion Usage Rate	41 Cleaning Difficulty	42 Main -tenance Difficulty	43 Cost
7	8	7	7	8	8	9	8	6	7	8	9	7	5	6	9	8	7
22			23			23			24			18			17		7
0.3181818	0.3636363	0.3181818	0.3043478	0.3478260	0.3478260	0.3913043	0.3478260	0.2608695	0.2916666	0.3333333	0.375	0.3888888	0.2777777	0.3333333	0.5294117	0.4705882	1
87	91	90	80	86	79	83	75	68	91	84	86	67	71	74	90	82	80

Example of Calculation Table

81.5486281145155																							
24.3335439560439												18.7587677025963											
1 Design Usability												2 Spatial Influences											
9												7											
30																							
0.3												0.233333333333333											
81.1118131868131												80.394718725413											
19.2307692307692				16.0416666666666		16.8791208791209		16.1076923076923		12.8525641025641		85365853	6	15		13.4878048780488		15.7637195121951		19.5578284815106			
1 Function Solution				2 Using Comfort Level		3 Interactive Level		4 Users Engagement		5 Safety Level		Acoustic Environ ment		Luminous Environment		Thermal Environment		Air Quality		Space Arrangement			
9				7		8		9		6		8		8		7		9		9			
39												41											
0.230769230769231				0.179487179487179		0.205128205128205		0.230769230769231		0.153846153846154		512195121		0.195121951219512		0.170731707317073		0.219512195121951		0.219512195121951			
83.3333333333333				89.375		82.2857142857143		69.8		83.5416666666666		85		76.875		79		71.8125		89.0967741935484			
27	17.6	22.4	16.333333	51.75	37.625	49.714285	32.571428	39.466666	30.333333	29.625	26.25	27.666666	85	29.625	23.333333	23.916666	40.5	38.5	41.625	30.1875	19.193548	25.548387	20.096774	24.258064
1 Function Needs	2 Function Display	3 Multi Pur -poses	4 Flexible Level	5 Ergonom ics	6 Tactile Touching Time	7 Using Difficulty	8 Inter -ference Factors	9 Engage -ment Role	10 User Numbers	11 Sharp Protru -sions	12 Flexible Elements	13 Use Zone Area	14 Noise Assess -ment	15 Natural Lighting Control	16 Artificial Lighting Control	17 View Block	18 Tempera ture Change	19 Humidity Change	20 Sharp Odor	21 Ventila -tion Change	22 Quiet Space	23 Active Space	24 Traffic Area	25 Activity Interrup -tion
9	6	8	7	9	7	8	6	8	7	9	7	8	8	9	8	7	8	8	9	7	7	9	7	8
30				16		14		15		24			8	24			16		16		31			
0.3	0.2	0.2666666	0.2333333	0.5625	0.4375	0.5714285	0.428571	0.5333333	0.4666666	0.375	0.2916666	0.3333333	1	0.375	0.3333333	0.2916666	0.5	0.5	0.5625	0.4375	0.2258064	0.2903225	0.2258064	0.2580645
90	88	84	70	92	86	87	76	74	65	79	90	83	85	79	70	82	81	77	74	69	85	88	89	94

Table 4.16 Table of Final Score Calculation

4.2.3 Final Delivery

In this case of application, designers need to provide two types of representation for their customers. The first package of representation will be the axonometric drawings, which is shown above. Parents and children could understand how the room grow and change by years. They are more like instructions for users. The second one will be the rendering images. They would provide an intuitional impression about what the design will display. Both of the representations are essential, so designers could not ignore each of them.

Figure 4.19 Children Room Age 0 to 3 Rendering

Figure 4.20 Children Room Age 3 to 6 Rendering

Figure 4.21 Children Room Age 6 to 12 Rendering

Figure 4.22 Children Room Age 12 to 18 Rendering

Figure 4.23 Children Room Age 0 to 3 Physical Model

Figure 4.24 Children Room Age 3 to 6 Physical Model

Figure 4.25 Children Room Age 6 to 12 Physical Model

Figure 4.26 Children Room Age 12 to 18 Physical Model

4.3 Construction Phase

The final step that designers need to participate is the construction phase. The construction phase is required to keep the whole design approach consistently. As the thesis discusses in the Chapter three, except for creating the concept, designers also need to contribute to the execution process of the space design. Designers can help the constructors to check the construction documents, manage the construction process, and supervise the room decoration.

Chapter 5 Conclusion

The thesis aims to create a design approach that can help children to have a growing room. The growing room can be flexible and adaptable so that it can fit children's different needs in various age periods.

The thesis is discussed and examined from three aspects. They are the adaptable room design, childhood development, and children residential space. Then, the design approach is developed based on three aspects. Designers need to follow three primary phases of the design approach, which are the preparing phase, the design phase, and the construction phase. Next, the thesis applies the design approach to create a children room.

As a conclusion, the thesis points out a possible approach of the children adaptable room design, but it still fails to investigate the profound and specific relationship between the space adaptability and childhood development. Even though the order of the concept generation is feasible in this thesis, the contents of the concept generation can be further explored. The exploration may bring more possibilities.

Reference

Adolph, K. E., & Franchak, J. M. (2017). The development of motor behavior. *Wiley Interdisciplinary Reviews: Cognitive Science, 8(1-2),* e1430.

Allen, P. S. (1985). *Beginnings of interior environment.* Burgess Pub. Co.

American Time Use Survey, Bureau of Labor Statistics. (2013). *How do U.S. high school students spend their time each week?* Retriveved April 24, 2019, from https://www.hhs.gov/ash/oah/facts-and-stats/day-in-the-life/index.html

Asendorpf, J. B., Warkentin, V., & Baudonniere, P. (1996). Self-awareness and other-awareness II: Mirror self-recognition, social contingency awareness, and synchronic imitation. *Developmental Psychology, 32,* 313-321.

Aslin, R. N., Jusczyk, P. W., & Pisoni, D. B. (1998). Speech and auditory processing during infancy: Constrains on and precursors to language. In D. Kuhn & R. S. Siegler (Eds,), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (5th ed., pp. 147-198). New York: Wiley.

Astington, J. W., & Jenkins, J. M. (1995). Theory of mind development and social understanding. *Cognition & Emotion, 9,* 151-165.

Bandura, A. (1991). Social cognitive theory of moral thought and action. In W. M. Kurtines & J. L. Gewirtz (Eds.), *Handbook of moral behavior and development* (Vol. 1, pp. 45-103). Hillsdale, NJ: Erlbaum.

Bertenthal, B. I. (1993). Infants' perception of biomechanical motions: Instrinsic image and knowledge-based constraints. In C. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 175-214). Hillsdale, NJ: Erlbaum.

Bench, R. J., Collyer, Y., Mentz, L., & Wilson, I. (1976). Studies in infant behavioral audiometry: I. Neonates. *Audiology, 15,* 85-105.

Berk, E. L., (2000). *Child Development.* Boston, MA: Allyn and Bacon, c2000.

Bradley, R. H., & Caldwell, B. M. (1982). The consistency of the home environment and its relation to child development. *International Journal of Behavioral Development, 5,* 445-465.

Bronson, G. W. (1991). Infant differences in rate of visual encoding. *Child Development, 62,* 44-54.

Caldwell, B. M., & Bradley, R. H. (1994). *Environmental issues in developmental follow-up research.* In S. L. Friedman & H. C. Haywood (Eds.), Developmental follow-up (pp. 235-256). San Diego: Academic Press.

Capizzano, J., & Adams, G., (2000). *The hours that children under five spend in child care: variation across states.* Variation across states.

Clifton, R. K., Rochat, P., Robin, D. J., & Berthier, N.E. (1994). Multimodal perception in the control of infant reaching. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 876-886.

Comer, J. P., (1984). Home-school relationships as they affect the academic success of children. *Education and urban society, 16(3),* 323-337.

Courage, M. L., & Adams, R. J. (1990). Visual acuity assessment form birth to three years using the acuity card procedures: Cross-sectional and longitudinal samples. *Optometry and Vision Science, 67,* 713-718.

Dobbins, T., (2018). *Shaping the future: what to consider when designing for children.* Retrieved May 30, 2019, from https://www.archdaily.com/901151/shaping-the-future-what-to-consider-when-designing-for-children/?ad_source=myarchdaily&ad_medium=bookmark-show&ad_content=current-user

Eisenberg, N., Fabes, R., Murphy, B., Karbon, M., Smith, M., & Maszk, P. (1996). The relations of children's dispositional empathy-related responding to their emotionality, regulation, and social functioning. *Developmental Psychology, 32,* 195-209.

Elliott, E. S., & Dweck, C. S. (1988). Goals: An approach to motivation and achievement. *Journal of Personality and Social Psychology, 54,* 5-12.

Fantz, R. L. (1961). The origin of form perception. Scientific American, 204, 66-72.

Friedman, A. (2002). *The Adaptable House: designing homes for change.* New York, NY: McGraw-Hill.

Friedman, A. (2001). *The grow home.* Montreal: McGill-Queen's University Press.

Getchell, N., & Roberton, M. A. (1989). Whole body stiffness as a function of developmental level in children's hopping. *Developmental Psychology, 25,* 920-928.

Ghim, H. R. (1990). Evidence for perceptual organization in infants: Perception of subjective contours by young infants. *Infant Behavior and Development, 13,* 221-248.

Gilliatt, M. (1985). *Designing rooms for children.* Boston, MA: Little Brown, 1985, c1984.

Gormley, J. E., & Williams, D. L. (2019). Providing Supportive Hospital Environments to Promote the Language Development of Infants and Children Born Prematurely: Insights From Neuroscience. *Journal of Pediatric Health Care.*

Hanington, B., & Martin, B. (2012). *Universal methods of design: 100 ways to research complex problems, develop innovative ideas, and design effective solutions.* Rockport Publishers.

Heidi, A. S., (1989). *Modern Montessori at home : a creative teaching guide for parents of children six through nine years of age.* Rossmoor, CA: American Montessori Consulting.

Hofsten, C. (1989). Motor development as the development of systems: Comments on the special section. *Developmental Psychology, 25,* 950-953.

Hogan, E. (1970). *Children's Rooms and Play Yards.* Menlo Park, Calif: Lane Books, c1970.

Howard, J. (2017). *Kids under 9 spend more than 2 hours a day on screen.* Retrieved April 20, 2019, from https://www.cnn.com/2017/10/19/health/children-smartphone-tablet-use-report/index.html

Huitt, W. (2008). *Educational Psychology Interactive.* Retrieved March 27, 2019, from http://www.edpsycinteractive.org/topics/affect/erikson.html

Huston, A. C., & Alvarez, M. M. (1990). The socialization context of gender role development in early adolescence. In R. Montemayor, G. R. Adams, & T. P. Gullotta (Eds.), *From childhood to adolescence: A transitional period?* (pp. 156-179). Newbury Park, CA: Sage.

Izard, C. E., Fantauzzo, C. A., Castle, J. M., & Haynes, O. M., Rayias, M. F., & Putnam, P. H. (1995). The ontogeny and significance of infants' facial expressions in the first 9 months of life. *Developmental Psychology, 31,* 997-1013.

Kaler, S. R., & Kopp, C. B. (1990). Compliance and comprehension in very young toddlers. *Child Development, 61,* 1997-2003.

Lewis, M., Alessandri, S. M., & Sullivan, M. W. (1992). Differences in shame and pride as a function of children's gender and task difficulty. *Child Development, 63,* 630-638.

Lifetime. (2018). *Adaptable children furniture.* Retriveved April 23, 2019, from https://www.skanvea.com/zixun/554.html

Lillard, P. P. (1996). *Montessori Today: a comprehensive approach to education from birth to adulthood.* New York, NY: Schocken Books.

Marsh, H. W., Barnes, J., Cairns, L., & Tidman, M. (1984). Self-description questionnaire: Age and sex effects in the structure and level of self-concept for preadolescent children. *Journal of Educational Psychology, 76,* 940-956.

Minami, K. (2007). A Post–Occupancy Evaluation of Layout Changes Made to KEP Adaptable Housing. *Journal of Asian Architecture and Building Engineering, 6(2),* 245-250.

Montessori, M. (1976). F*rom childhood to adolescence: Including "Erdkinder" and the functions of the university.* New York, NY: Schocken Books.

Nichols, J. L., & Adams, E. (2013). The flex-nest: The accessory dwelling unit as adaptable housing for the life span. *Interiors, 4(1),* 31-52.

O'Brien, M., & Huston, A. C. (1985). Development of sex-typed play behabior in toddlers. *Developmental Psychology, 21,* 866-871.

Permafrost. Retrieved April 23, 2019, from http://permafrost.no/projects/Stokke_Steps_children's_seating_system

Piaget, J., Inhelder, B., & Szeminska, A. (1960). *The child's conception of geometry.* New York: Basic Books. (Original work published 1948)

Rokos, B. (2018). *Physical, psychological recovery of 13 children held captive in California house expected to be long-term.* Retrieved April 21, 2019, from https://www.mercurynews.com/2018/01/17/physical-psychological-recovery-for-perris-children-expected-to-be-long-term/

Ruth, C, L. (1999). *Design Standards for Children's environments.* New York, NY: McGraw-Hill.

Saarni, C. (1997). Emotional competence and self-regulation in childhood. In P. Salovey & D. J. Sluyter (Eds.), *Emotional development and emotional intelligence* (pp. 35-66). New York: Basic Books.

Saarni, C., Mumme, D. L., & Campos, J. J. (1998). Emotional development: Action, communication, and understanding. InN. Eisenberg (Ed.), *Handbook of child psychology: Vol. 3. Social, emotional, and personality development* (5th ed., pp. 237-309). New York: Wiley.

Sanders, L. (2017, June 22). *When should babies sleep in their own rooms?* Retrieved March 27, 2019, from https://www.sciencenews.org/blog/growth-curve/when-should-babies-sleep-their-own-rooms

Schneider, T., & Till, J. (2005). Flexible housing: opportunities and limits. *Arq: Architectural Research Quarterly, 9(2),* 157-166.

Signorella, M. L., Bigler, R. S., & Liben, L. S. (1993). Developmental differences in children's gender schemata about others: A meta-analytic review. *Developmental Review, 13,* 147-183.

Slater, A. M. (1997). Visual perception and its organization in early infancy. In G. Bremner, A. Slater, & G. Butterworth (Eds.), *Infant development: Recent advances* (pp. 31-53). Hove, England: Tylor & Francis.

Stack, D. M., & Muir, D. W. (1992). Adult tactile stimulation during face-to-face interactions modulates five-month-olds' affect and attention. *Child Development, 63,* 1509-1525.

Tucker, E., (2016). *Teehee designs adjustable furniture that grows up as children do.* Retrieved April 23, 2019, from https://www.dezeen.com/2016/10/03/teehee-kids-adjustable-customisable-units-childrens-furniture/

Vasel, K., (2017). *It costs $233,610 to raise a child.* Retrieved May 30, 2019, from https://money.cnn.com/2017/01/09/pf/cost-of-raising-a-child-2015/index.html

Wellman, H. M. (1990). *The child's theory of mind.* Cambridge, MA: MIT press.

Wylde, M. A., (1994). *Building for a lifetime: the design and construction of fully accessible homes.* Newtown, CT: Taunton Press.

Zajonc, R. B. (1976). Family configuration and intelligance. *Science, 192,* 227-236.