Usability Problems and Design Solutions of LEGO Duplo, Including Bricks and Instructions

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Abstract
LEGO Duplo is an excellent educational product especially for children between 1.5 and 5 years old. However, there are several usability problems which occur when a child is playing with it. Therefore, this study applies graphic design and augmented reality (AR) to solve these problems.Research Process is composed of five steps:
1. Analyzing LEGO Duplo and its instructions 2. Observing how a child is playing with LEGO Duplo and discovering usability problems 3. Developing prototypes for a better design 4. Analyzing and improving the prototypes 5. Verification of the research results. Usability problems discovered include (1) incomplete instructions; (2) confused information; (3) blind angles; (4) vague outline; (5) wrong distance; (6) wrong direction; (7) uneven height; (8) loose assembly. Then, design solutions are prototyped as bricks, instructions, and AR simulations. Graphic pattern on bricks includes “arrow, alignment, and minimum height markers”. They deal with problems including wrong direction, loose assembly, and uneven height, respectively. In addition to ordinary instructions, more instruction cards are prototyped. They show completely assembled bricks which is difficult to complete for the child. Each card also works as an AR marker that activates an animated simulation. Each animation with 360 degrees of view helps the child to solve the rest of problems as well as to accomplish brick assembly. According to test results, the authors conclude that AR absolutely can solve or reduce most of Duplo’s usability problems. However, no acceptable solution to the “loose assembly” problem is found and, unexpectedly, the markers on bricks has limited effectiveness.

Keywords: LEGO Duplo, Usability Problems, Design Solutions, Augmented Reality, AR, Brick Instructions

Introduction

LEGO Duplo is an excellent educational product especially for children between 1.5 and 5 years old. However, there are several usability problems which occur when a child is playing with it. Therefore, this study applies graphic design and augmented reality (AR) to propose several ways to solve these problems. This project lasted for one year and it is a part of a Master's thesis.

Background

The background of this research are three-fold:

(1) Traditional instructions with paper-based text, symbols, and graphics are the most common and inexpensive way to show operation procedure but the deficiencies such as misunderstanding are clear.
(2) The popularization of augmented reality and smart devices help people to select and deal with information difficult to demonstrate or understand.
(3) The happening trend of E-learning makes it possible that all people including children are able to learn and therefore to acquire knowledge through connected devices.

Motivation

Due to the impact of the baby bust, an increasing number of parents are willing to spend more time and money on their children. This spend is particularly unstinting with regard to education. Duplo, produced by LEGO, has always been one of the best choices for parents. However, usability problems frequently occur when children are playing with the bricks. For example, one child may build mistakenly even if trying hard to follow the instruction step by step. These problems reduce the functionality of LEGO Duplo. If Duplo's problems can be analyzed and discussed, Duplo's educational effectiveness will be enhanced and it must further enrich the learning of children who are playing with it.

Literature Review

Literature review include three categories: prior studies about children, augmented reality, and instruction manual. The categories and references are briefly shown in table 1.

Research Methods and Process

The process of this research includes five stages, each of which is extended below.

1. Analyzing LEGO Duplo and its instructions
2. Observing how a child is playing with LEGO Duplo and discovering usability problems
3. Developing prototypes for a better design
4. Analyzing and improving the prototypes
5. Verifying the research results

1. Analyzing LEGO Duplo and its instructions

Duplo instructions can be divided into three categories, as shown in figure 1:

(1) 46% are general instructions;
(2) 38% are packing instructions;
(3) 15% are cartoon instructions.

General instructions are booklets, each of which shows how a certain brick set is built step by step with consecutive perspective pictures in detail. Packing instructions are simple scenario pictures printed on packages, each of which shows how a certain brick set looks like and/or how it is played or displayed after completely assembled. Last, cartoon instructions are cartoonish pictures printed on sheets, each of which usually shows how a brick set looks like or how it is displayed after completely assembled. With just single set and simple cartoon pictures, it is easy to be understood by children.

Table 1: The categories and references of literature review.

Categories	Sub-categories	Author name(s) (Year)
1. Children	1-1 Definition of Children	Huang (1999)
	1-2 Cognitive development of Children	Tseng (2012) Li (2010)
	1-3 Reading motivation and improvement of learning effect	Lefever-Davis & Pearman (2005) Lee (2015) Liao (2011)
	1-4 Digital Multi-media aided Learning	Mayer (2005) Lai (2013)
2. Augmented Reality	2-1 Definition of AR	Augmented reality (2015) Azuma et al. (2001)
	2-2 History of AR	Feiner, MacIntyre, Haupt, & Solomon (1993) Sutherland (1968)
	2-3 Principle of AR	Wagner & Schmalstieg (2007) Wagner, Langlotz, & Schmalstieg (2008) Zhang, Fronz, & Navab (2002)
3. Instruction Manual	3-1 Common problems of instructions	Li (1999) Wu (2012)
	3-2 Ways to write an effective manual	Norman (2005) Huang (2011)

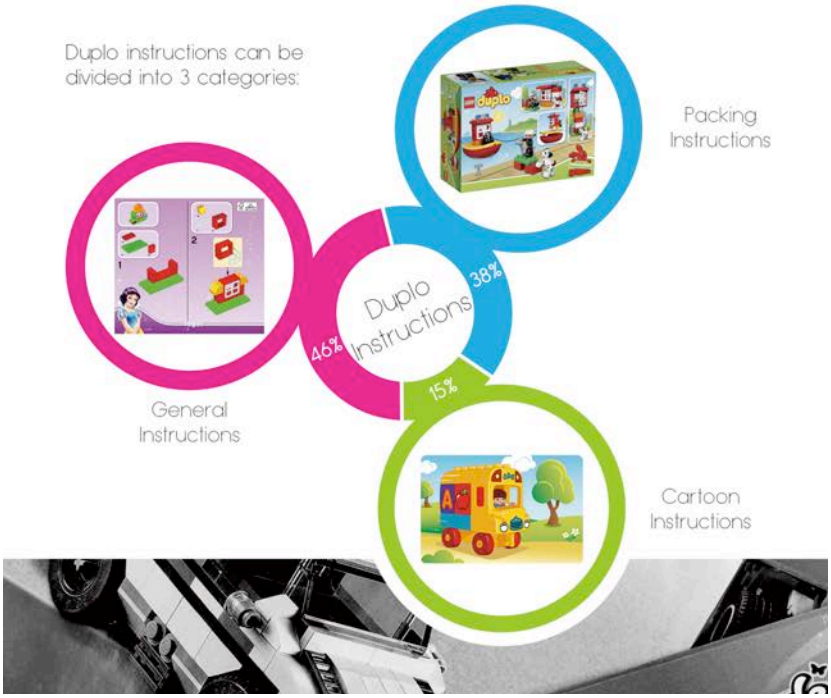


Figure 1: The three categories of LEGO Duplo instructions.

2. Discovering usability problems

Eight different types of usability problems, as indicated in figure 2, are discovered based on observing how a child is playing with LEGO Duplo.

(1) Incomplete instructions: most of LEGO Duplo's instructions are merely one or several sheets of assembled pictures with or without cartoon scenario. They are not perfect for children to understand dynamic building process.

(2) Confused information: confused information is what makes the child subject hesitate or misunderstand. Usually, it is a step, a picture, a symbol, or an icon that results in confusion.

(3) Blind angles: blind angles are what the child subject needs to see or read but he cannot do it or cannot find it. They make the subject temporarily stop assembling bricks.

(4) Vague outline: if two adjacent bricks have the same color, it is difficult for the child subject to identify the joining edge between bricks in the instruction. Therefore, the subject must spend more time for completing the assembly.

(5) Wrong distance: the child subject often mistakenly measure lengths. For example, as shown in figure 2, the distance between the two blue bricks is longer than the length of the red arch brick in the picture. It results in the pause and repetition of building steps.

(6) Wrong direction: due to the standard modular design of LEGO Duplo, direction is the key for correct assembly and great fun. However, some bricks with similar shape

but different direction may mislead the child subject to be confused with wrong direction and wrong assembly.

(7) Uneven height: the child subject often miscount or ignore the height of any two bricks. It results in the temporary failure of bridging and/or assembly.

(8) Loose assembly: the child subject often ignore the tightness of bricks. It results in the falling of the bricks.

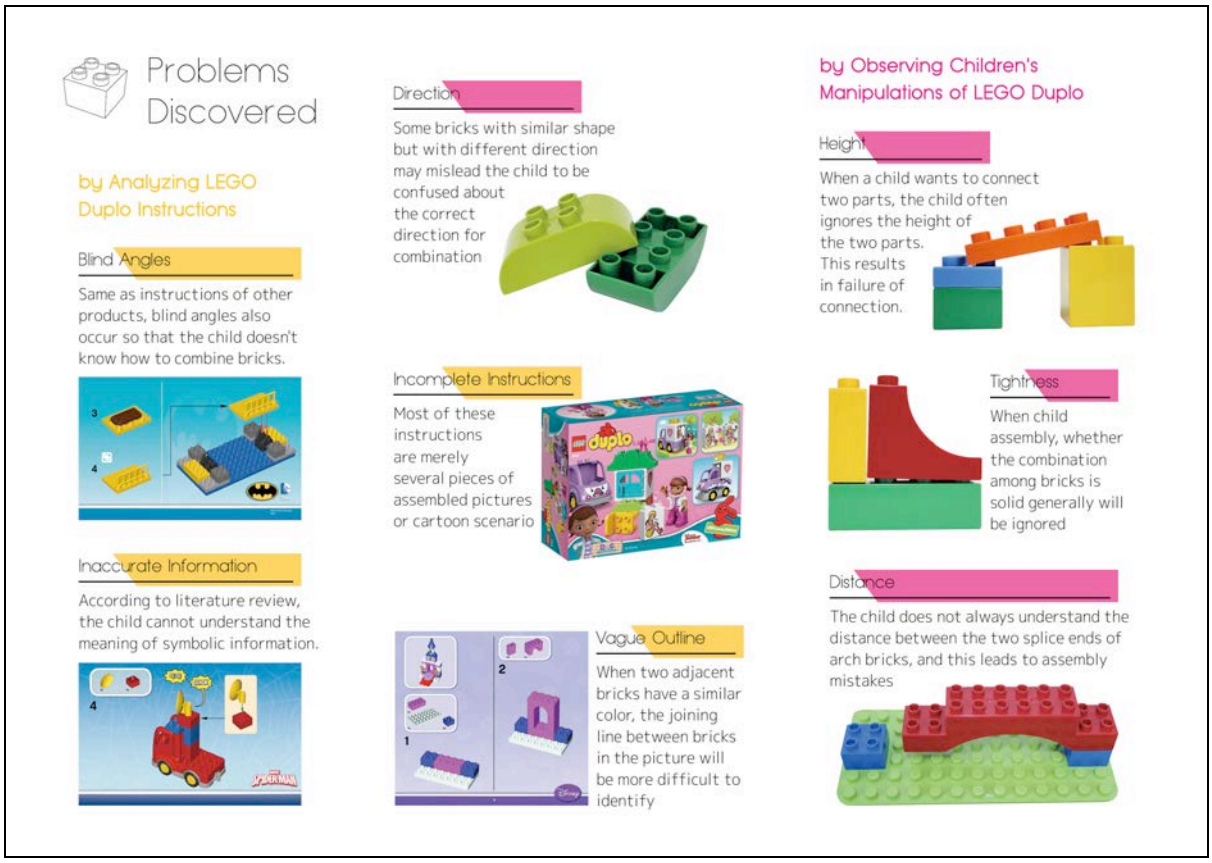


Figure 2: Eight different types of usability problems.

3. Developing prototypes

Based on each of the eight usability problems, eight prototypes or solutions are developed.

(1) Incomplete instructions: incomplete instructions do not reach a balance between "accurate information" and "children's reading interest." Therefore, the authors propose a new type of LEGO Duplo instructions in order to keep children interested in reading and keep instructions as clear as possible. First, instruction cards are adopted. Each of the cards shows a graph of completely assembled bricks and it works as an Augmented Reality (AR) marker. Second, AR simulation is developed for clearly demonstrating how difficult steps are completed.

(2) Confused information: the animated AR simulation with audio not only replaces the confused information such as picture, symbol, and text description but also makes the child subject understand the instruction.

(3) Blind angles: to minimize this problem, AR is applied to display 360 degrees of 3D models of bricks without blind angles.

(4) Vague outline: with 360 degrees of 3D simulation, AR simulations can clearly display the outline of two bricks with the same color.

(5) Wrong distance: based on usability tests, the authors figure out that the child subject relies on counting bulges on bricks to measure distance during assembly. So, AR simulation must show numbers that indicate the distance between bricks whenever it is necessary.

(6) Wrong direction: usability tests help to figure out that the child subject assembles bricks in a correct direction if a cartoon bear image printed on the brick, as shown in figure 3. On the other hand, according to literature review, arrow markers printed on bricks may have a strong sense of direction for children, although he does not know why they are there. Thus, the authors apply cartoon image and arrow markers to help children subject to recognize the direction of bricks.

(7) Uneven height: the authors apply “minimum height markers” and “rulers on bricks” to solve the problem of uneven height. All bricks are marked with minimum height (9.6mm) markers to make the child subject understand the concept of height. In addition, the subject can see cartoon animals, ruler indicators printed on bricks, as a visual tool for measuring heights of any two bricks to be compared, bridged, or assembled.

(8) Loose assembly: to make the child subject assemble LEGO Duplo tightly, the authors propose two solutions: “alignment markers” and “luminous splices”. Simple but aligned markers are printed on each brick so that bricks assembled loosely causes visually deflective gaps between patterns on bricks. These patterns may remind children of the looseness problem. Differently, luminous splices means painting luminous pigment on bulges on bricks. When there are gaps between bricks, gleam emitting from the gap may remind the child that bricks are not assembled tightly.

Figure 3: Prototypes of LEGO Duplo instructions.

4. Analyzing and improving the prototypes

Because the child subject's hands take bricks at all times when playing with LEGO Duplo, it is very difficult to carry out any operation such as AR simulation on mobile devices. Consequently, this research uses an All-In-One PC with a larger size of touchscreen instead of a tablet or smart phone. During tests, the child is playing with LEGO Duplo bricks and facing the PC touchscreen that is placed behind the Duplo set. When each assembly problem occurs, what the child needs to do is to place instruction cards (AR markers) under the camera lens to activate the AR simulation. It makes the problem-solving process more convenient.

Each AR marker conventionally is a square with abstractive shape in black and white. They are too odd to be used in LEGO Duplo's instruction. Thus, this research applies Vuforia to develop the AR system. Vuforia makes it possible that any graphic instruction of LEGO Duplo can be used as an AR marker. That is, each instruction card is an AR marker for a better animated instruction. To redesign LEGO Duplo bricks as less as possible, this research integrates "arrow, alignment, and minimum height markers" together as "comprehensive pattern" without cartoon animals, as shown in figure 4.

5. Verifying the research results

The verification include the test of (1) paper-based instruction cards, (2) animated AR simulation as additional instructions, and (3) graphic comprehensive patterns, as

shown in table 2, 3, and 4, respectively. On the other hand, additional devices and operation necessary for verification are described below:

(1) LEGO Duplo bricks: for each test, LEGO Duplo bricks with comprehensive patterns are placed in a box produced by LEGO. Based on most Duplo instructions, the first step always starts with a floor brick. So, the child is provided with a big floor brick in each test.

(2) Instruction cards: in addition to AR system, more instruction cards are prototyped. They show completely assembled bricks which is difficult to complete for the child. Each card also works as an AR marker.

(3) Augmented reality system: as the user of the AR system is a child, the way to run this system must be quite easy. When the child encounters any assembly problem, he just needs to place the instruction card under the camera lens and then the AR instruction initiates immediately.

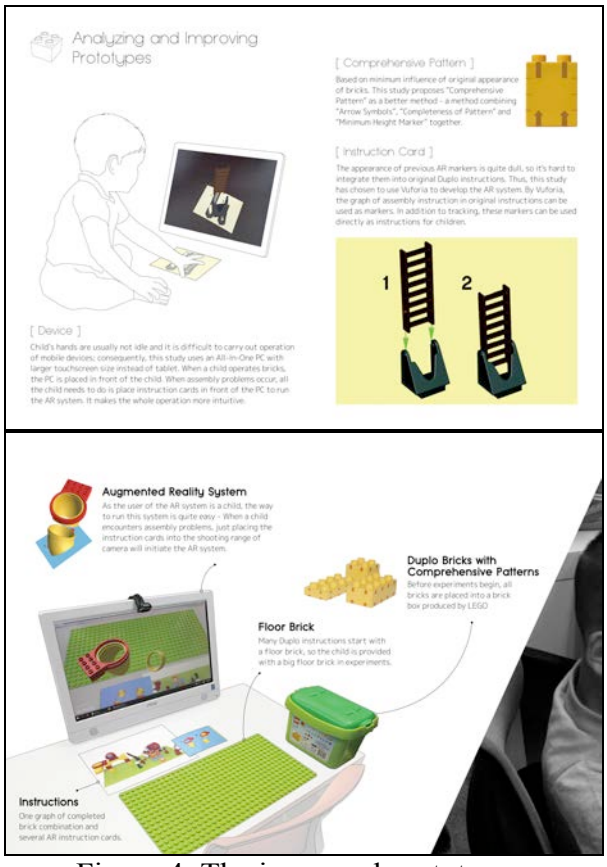


Figure 4: The improved prototypes.

Table 2: Verification of paper-based instruction cards.

Problem 01	Assembly instruction is not complete
Solution 01	(1) New paper-based instruction cards (2) AR system
Description of Solution	Two types of instruction cards are applied: one shows completely assembled bricks which is difficult to complete for the child. Each card also works as an AR marker that

	activates an animated simulation. The other type shows what the whole set looks like after completing that step. The AR system also shows the animated simulation of the first type.
Result	Instruction cards and AR system help the child subject to assemble bricks better.
Photo Demonstration	

Table 3: Verification of AR instructions.

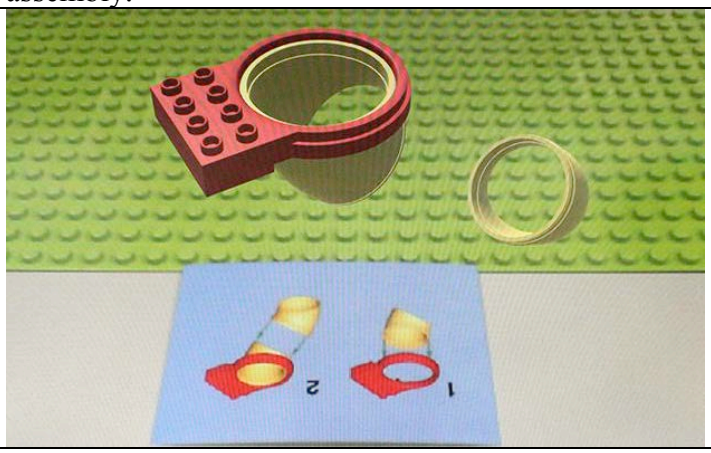
Problem 02	Confused information, instructions with blind angles, vague outline, and wrong distance
Solution 02	AR system
Description of Solution	AR system shows the animation of how LEGO Duplo bricks assembled without blind angles. It clearly demonstrates the movement of parts in distance and visual difference of completing each step of assembly. There is also a sound effect indicating the assembly. This AR system makes the instruction complete and vivid.
Result	Each animation with 360 degrees of view helps the child to solve the rest of problems as well as to accomplish brick assembly.
Photo Demonstration	

Table 4: Verification of graphic comprehensive patterns.

Problem 03	Wrong direction, uneven height, loose assembly
Solution 03	Graphic comprehensive patterns
Description of Solution	The graphic comprehensive pattern on bricks includes “arrow, alignment, and minimum height markers”. They deal

	with problems including wrong direction, loose assembly, and uneven height, respectively. For verification, the graphic patterns are actually color-printed transparent stickers on LEGO Duplo bricks.
Result	Comprehensive patterns do not help the child subject to better assemble LEGO Duplo bricks.
Photo Demonstration	

Table 5: The result of verification.

How problems are discovered?	Problems	Solution	Problem solved or not
Analysis of instructions	Incomplete instructions	New paper-based instruction cards & AR	Yes
	Blind angles	AR	Yes
	Confused information	AR	Yes
Observation	Wrong direction	Comprehensive patterns	No
		AR	Yes
	Loose assembly	Comprehensive patterns	No
	Uneven height	Comprehensive patterns	No
		AR	Yes
Verification	Vague outline	AR	Yes
	Wrong distance	Numbers in AR	Yes

The result of verification indicates that both new paper-based instruction cards and AR system work well for helping the child subject to better play with the LEGO Duplo bricks, as shown in Table 5. That is, the subject encounters no/less difficulties and makes no/less mistakes. However, the graphic comprehensive patters does not help to solve the corresponding problems.

Conclusion

This research finds out usability problems and proposes design solutions of LEGO Duplo, including bricks and instructions. According to the test results, it is clear that the AR system functioning as instructions helps to solve most of the usability problems except the “loose assembly”. However, the "comprehensive pattern" has limited effect on all problems. Based on the child subject's feedback to the AR simulation and playing behavior in the tests, this research asserts that the looseness problem may be mitigated if the child subject watches an educational video about tightness every time right before playing with LEGO Duplo. Furthermore, as technology advances, intelligent light wearable devices that will not negatively

influence children’s action may be used as the carriers of AR system. In this way, the application of AR simulation can make instructions smoother and more intuitive.

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