Development of User-centered design process for Brain-Based Learning toys

Sakol Teeravarunyou[a*] and Pongsak Kitirojpan[b]

School of Architecture and Design, King Mongkut's University of Technology Thouburi, 49 Soi Tientalay 25, Bangkhutien-Chitalay Road, Bangkhutien, Bangkok 10150 Thailand
[a*]sakol.tee@kmutt.ac.th, [b] pongsak.kit@kmutt.ac.th

Abstract

Office of Knowledge Management Development (OKMD) initiated a project integrating the Brain-Based Learning and toys. As many educators are not trained as designers and neuroscientists, it is difficult for them to apply knowledge from education and neuroscientists in designing tangible toys. In this paper, the researchers examine how to use the user-centered design process to carry out toy development. Sixty subjects, kindergarten educators and toy designers, joined the three days workshop to design toys for children aged 3-5 years old. For the first day, the basic information of brain functions and child development was given by neuroscientists. Then ten teams with educators and designers did ethnographic observation at the Foundation of Children, brainstorming and mock-up (recycled material and paper). Fourteen mock-up toys were produced then filtered out by usability testing. The expert committee evaluated the toys by using a rubric tool and provided a fund for prototypes. The results show that user-centered design process is effective to apply the knowledge of neurosciences and education for Brain-Based Learning toys. Nine toy prototypes were produced and exhibited to the public with a positive feedback from visitors.

Key words: Brain-Based Learning, toys, user-centered design process

1. Introduction

Brain-Based Learning (BBL) is a comprehensive approach to instruct using current research from neuroscience. Brain-based education emphasizes how the brain learns naturally and it is based on structure and function of the human brain at varying developmental stages [1]. Several models of neuroscience and cognitive science can be used to explain the BBL. For example, the mirror neurons and theory of mind-reading are the concepts that illustrate how the monkey learns by copying the goal-related motor actions [2]. Another famous research is Mindfulness of Symbols. DeLoache built a model of room with the purpose of studying toddler memory. The result shows how three-year-old toddler performed the retrieval task better than the two-and-a half-year-old toddlers [3]. Although these models are useful, not so many designers apply these models for toy design.

Hirsh-Parsk and Bruer said that the educational literature is now stocked with books and articles boosting brain-based curricula and practices so the market has grown for brain-based toys. The message of synaptic growth and critical period has affective appeal, but no scientific substance. This enthusiasm has caused us to neglect research that tells us how children learn [4]. Educators need to be cautious about things that are based on research of the brain. Not all things are valid. Some brain researches have been used inappropriately to support education policies [7].

Several workshops of toys were arranged in the past such as UNESCO toys workshop for children's rehabilitation [6]. Mom-made toys [8] have quite specific and clear objectives, for example, an emotional face toy used for autistic or cerebral palsy child. Nevertheless, those toys cannot be used for general purpose. It is difficult to distinguish how BBL toys differ from ordinary toys in the market.

1.1 Background

Office of Knowledge Management Development initiates a project that is a combination between BBL and toys. The delivery output is the ten toys that have the concept of BBL. In order to carry the team to the end of the workshop, user-centered design process is used as a good model for multidisciplinary approach. The example can be seen from the Deep Dive Nightlines – the grocery shopping cart project from the IDEO Company [9]. The project is combined with the team members from many fields such as anthropology, marketing, industrial design and engineering. The process of User-Centered Design (UCD) is starting from observing users in the grocery shop with hundreds of photos. Then the team brainstormed and built shopping carts within 7 days. The result is impressive and shows how multidisciplinary team carried out the work. The UCD is appropriate for the BBL toy project, since the team uses a child as a center for design. Nevertheless, IDEO project did not show how their products work in the real situation. They received the feedback only from the grocery cashier. The BBL toys project is complex, since it is related to the brain and behavior of play. It is impossible to predict that children will play, since the ones who design are adults. As a result,

the user testing (usability testing) is used to validate the concept before production.

UCD or Human-Centered Design process is a guideline in ISO 13407 [5]. The ISO standard describes it as a multi-disciplinary activity, which incorporates human factors and ergonomics knowledge. There are four activities that are need to start at the earliest stages of a project. These are to: 1) understand and specify the context of use, 2) specify the user and organizational requirements, 3) produce design solutions, and 4) evaluate designs based on the requirements. This process was applied for the BBL workshop. For the first stage, the participants in the workshop identified and documented user's tasks. They recorded how children played toys and determined the principle of neuroscience behind the play. For the second stage, the participants set the objectives through brainstorming and discussion. For the third stage, the design solutions were carried out in terms of mock-ups and prototypes. For the fourth stage, early prototypes/mock-ups were evaluated by usability testing to ensure that they had met organizational and user needs.

1.2. Objectives

The aim of this research is to examine the user-centered design process to carry out the toy development. The research questions are the following:

- How does user-centered design process facilitate the cooperative working among disciplines?
- In which way, the toy can serve the principle of Brain-Based Learning?

2. Method

The workshop was designed for three days activities as can be seen in Table 1 from October 5-7, 2012. Sixty subjects were made up of kindergarten, elementary educators and toy designers. Toy designers came from SMEs with their own manufacturing toys and educators and designers made up ten teams. The first day was about information gathering and tuning such as lecture and brainstorm. The process of tuning by lecture was to ground an understanding for both designers and educators. All of them were requested to visit the Foundation of Children and to collect data by shooting photos of children's behavior from 5 stations. For the second day, all teams posted their photographs and post-it notes on the wall. They analyzed the data that they collected and brainstormed the design by using mind mapping techniques and sketching. Then they started to make several mock-ups from paper and recycled materials. The time of making mock-ups was approximately 4 hours. The mock-up was a representation of toys that could be modified quickly. Each group presented their mock-up toys to the experts. Then all groups redesigned their mock-ups according to experts' critiques. For the last day, all groups took the mock-ups to the Foundation of Children and tested them with at least two children. In each group, the test monitors watched how children played their mock-ups and recorded with video cameras. They presented the result of usability testing to the neurologist and toy experts.

Table 1. Time schedule of workshop

	Activities
Day 1	Lecture of child's brain and toys by education experts
	Ethnographic observation at the Foundation of Children with 5 stations – cooking food, playground, toy playing, art, and Montessori classroom
	Discussion of observation result with a neuroscientist
	Lecture of child development and play by toy designer
	Lecture of User-Centered Design process by experts
Day 2	Team brainstorming
	Mock-up of toys
	Group presentation of toys and critiquing by experts
	Redesigning according to the experts' comments
Day 3	Usability testing of the mock-ups at the Foundation of Children
	Group presentation of result from usability testing Critiquing by neuroscientist and toy experts

Table 2. Rubrics of Brain-Based Learning toys

BBL index	Criteria		
	Level 1	Level 2	Level 3
1. Attractive to play	Using eye contact during the play	Using eye and hand contact during the play	Touching and exploring the toys
2.Build concentration	Playing less than 1 min.	Playing between 1 to 5 minutes and eager to play	Playing continuously more than 5 minutes
3. Stimulate brain and child development	Using fine motor or gross motor skills	Using both fine and gross motor skills	Using motor skill with other senses such as eye, ear and tactile
4. Play with happiness and cheerfulness	Happy face while playing	Responses of play such as smile and laugh	Playing without stop
5. Challenge idea, knowledge and performance	Attempting to solve the problem	Playing and be able to solve the problem	Playing out of the limit and challenging
6. Increase social interaction	Playing alone	Playing and inviting others to play	Understanding others both thinking and emotion
7. Real imitation and experience sharing	Playing without knowing what is it	Role playing and imitating the toy as a real thing	Extend play
8. Repeating play	Trial and error	Play until finish	Playing until finish and replay
9. Appropriate and safe for 3-6 years	Toys not too small and sharp	Play method should be safe.	Appropriate to the child's age
10. Roadmap of play	Having a basic level of play	Playing from easy to difficult	Creating their own strategy of play

After the workshop, a committee from OKMD who are specialists in neuroscience, toy design, education and

management evaluated the mock-ups by using the rubric tool which had been created by the neuroscientist (see Table 2). The BBL evaluation has been measured in term of achievement and motivation [1]. After selection, the committee funded the SMEs for prototypes. The time of production was nearly eight months.

3. Results

The result is an output of the workshop which is a mock-ups and prototypes. The mock-ups represent the development of the idea which is being tested with users. The prototype is the final design that has been commented from the expert committee.

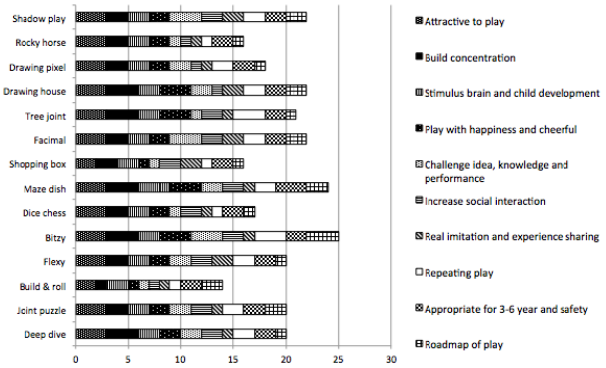
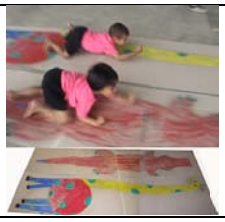


Figure 1. Result of rubrics

3.1 Assessment of mock-ups with rubrics score and usability testing

Table 3. Mock up results from the rubrics and usability testing

Toy names	Descriptions	Rubrics score	Usability testing
1. Deep dive	Large mat of sea animal with geometrical shapes as puzzle 	20	Many subjects enjoy with the matching of the shape and they built a story during the play.
2. Joint puzzle	Cubic shape with joints 	20	Subjects who noticed the joint could figure out the puzzle more quickly than subjects who did not notice the details of joint.
3. Build and roll	Build components to play a metal ball 	14	Subjects had a difficult time to understand how to play. They could not figure out how the things were connected together.
4. Bitzy flexy	Long mat for children to crawl and run 	20	Subjects enjoyed when they had the competition. They used their bodies to move. The paper floor was too hard for children to crawl.
5. Bitzy	Flexible wire that can be constructed as figures 	25	Subjects paid attention on the toys more than one hour. They could play both free play and assignment.
6. Dice Chess	Chess mat with dice for players to stand on 	17	Subjects enjoyed to play with dice but the mat was too short and many of them were confused about the rules of play.
7. Maze dish	Controlling the ball from the outside to the center of dish 	24	Subjects could not collaborate when they played with multiple balls but they could handle well with only one ball.
8. Shopping box	Theme play for lady shopping 	16	Subjects did not understand how to play with the toy.
9. Facimal	Components of animal faces that can be put together as puzzle 	22	Subjects paid attention and tried to solve the problem by placing the face components together.
10. Tree joint	Joint that hanged on tree for players to climb on a rope. 	21	Subjects felt challenged when they climbed across the tree. The toy may not be safe in many parts when they grabbed or stood on a rope.
11. Drawing house	Paper house that can be used for drawing	22	Subjects wanted to draw images inside the house more than outside. They spent a lot of time with this toy. The paper house was too small and

Toy names	Descriptions	Rubrics score	Usability testing
			should be seen clearly by parents
12. Drawing pixel	Circle plate for drawing alphabet 	18	Subjects painted and wrote on the paper. There was no goal of learning.
13. Drawing rocky horse	Rocky horse that can be used for drawing and erasing 	16	Subjects drew on the horse. Ink may make children's clothes dirty.
14. Shadow play	Theatre that is a projection of figures 	22	Subjects placed the figure on the foam to see the shadow.

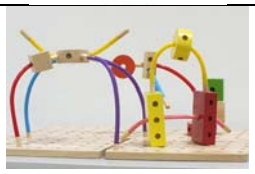
Fourteen mock-ups were designed by ten teams. Result showed that five mock-ups were lower than 20 points. The committee decided to select the toys which were above 20 points for production. The reasons for lower scores could be classified into three problems. First, the toys were difficult to play such as 'Build and Roll'. The toys were designed by using a mindset of the designer not of the child. The designer did not integrate the knowledge of neuroscience into the design, such as the cognitive and motor skills of a child. Second, the toy was too easy to play. 'Dice Chess' showed that the subjects finished the play early without a clear roadmap of play. They did not return to play for the second time. Third, the toy was not interesting and was lack of ultimate goal. 'Shopping box' showed that subjects could not link the experience of shopping to their plays. They were too young for this type of toys. 'Drawing rocky horse' did not have any feedback to show the success of play.

'Bitzy', Maze dish', 'Shadow play', 'Drawing horse' and 'Facimal' had the highest rubrics score respectively. Subjects paid attention to the 'Bitzy' the most. They spent at least 40 minutes to play this type of toys for it supported the creativity and imagination of the children. Subjects felt relaxed when they played the toy. 'Maze dish' was played well in term of social interaction and problem solving. This result was similar to what Craine and Cain mentioned. The brain is social by nature. It develops better in concert with other brains [1]. This toys allowed problem solving through synchronization among the children.

3.2 Prototypes

The final toys or prototypes were exhibited at Thailand Creative and Design Center (TCDC) on May 14-20, 2013. Visitors from the exhibition were allowed to play the prototypes and gave several feedbacks. Many of them gave a good positive feedback especially for Maze dish, Drawing house and Bitzy.

Table 4. Prototypes of toys

Toy names	Prototypes	Concept	Neuroscience keywords and expected brain region
1. Deep dive		Modular pillows of animal shapes that can be played as puzzle.	Imagination, Symbol to reality Brain function: Temporal and occipital region
2. Joint puzzle		Puzzle images of sport cartoon and real images.	Working memory, Visuospatial sketchpad, Problem solving Brain function: Temporal and occipital region
3. Bitzy flexy		The mat can be joined in any order with tunnels and high-relief footstep.	Gross motor skills, Body balance, Movement, Social interaction Brain function: Motor cortex
4. Bitzy		Joint made from wood with holes for wires to connect other joints.	Fine motor skills, Hand-eye coordination, Creativity Brain function: Motor cortex
5. Maze dish		Three handles are placed around the dish. The obstacle is animal shapes function like bridge and forest.	Social interaction, Problem solving Brain function: Pre-frontal cortex

Toy names	Prototypes	Concept	Neuroscience keywords and expected brain region
6. Shape config		Animal faces like pig, rabbit, elephant and bear are designed to place with body, ear and legs.	Perception, Top-down/Bottom-up processing Brain function: Temporal and occipital region
7. Tree joint		Adaptive joints that can be hung on trunks of trees with several designs of rope pattern.	Gross motor skills Brain function: Motor cortex
8. Drawing house		Plastic house that can be drawn and erased with color.	Mindful of symbol, Imagination Brain function: Temporal and occipital region
9. Shadow play		Multiple slides with shape that can be combined.	Visual perception, Top-down processing Brain function: Temporal and occipital region

To summarize how the toys serve the concept of BBL, neuroscience keywords are concluded as seen in Table 4. All toys can be clustered into four groups. First, the toys that are related to imagination are 'Deep dive' and 'Drawing house'. Children can use their own imagination from ready figure or can build their own without instruction. Second, the toys that support the visual perception are 'Shape config' and 'Shadow play'. They need to have a skill to assemble and dismantle. Third, the toys that support the motor skills are 'Bitzy', 'Bitzy flexy' and 'Tree joint'. These types of toys focus on fine or gross motor skills. Fourth, the toys that support the problem solving skills are 'Joint puzzle' and 'Maze dish'. These toys require mathematical, logical and planning skills.

4. Conclusion

The UCD process is effective as it gives the opportunity for educators and toy designers to exchange their knowledge and experiences during the workshop.

- By using ethnographic observation and usability testing, the participants understood how children reacted to the toys.
- BBL toys in this project could enhance the skills and competencies such as problem solving, creativity, social interaction, perception and motor skills.

The shortcoming of this research is that the linkage between toy and neuroscience/cognitive psychology is not quite clear when developing the toys. Some designers tend to lead the project with their preferences, so there is a minimal BBL knowledge that can be applied to the toys. Some educators design the toys like teaching materials instead of toys. The major shortcoming is that aspect of BBL is difficult to verify scientifically and it requires several high-end equipment such as brain activity scanner.

For further development, some variables may need to be investigated such as instruction manual of toys, guidance from parents/teachers, and surroundings. To prove the effectiveness of BBL toys, scientific tools are required to measure brain activity during the play stage. To strengthen the process of UCD, the participants for the workshop must include knowledgeable members who are specialists in the area of neuroscience.

5. Acknowledgements

This research was supported by OKMD for workshop and toy manufacturing companies. We would like to thank various people for their contributions to this BBL workshop, including Prof. Dr. Prasert Boongird, who is a neuroscientist, for his valuable and constructive suggestions during the planning and development; Assoc. Prof. Narishchara Luendaragarnon, M.D., Pornpilai Lertvichai and Miss Rattikorn Wuttikorn for sharing their knowledge in the workshop; and Mr. Kochahem Kamolwit and Mrs. Suprasee Weswiboon for assisting the workshop.

6. References

[1] Caine G., Nummela-Caine R., and Crowell S. Mindshifts: *A Brain-Based Process for Restructuring Schools and Renewing Education*, 2nd edition. Tucson, AZ: Zephyr Press. 1999.

[2] DeLoache S. Judy. *Mindful of Symbols*, Scientific American, 17, 30-35. Doi:10.1038. 2007.

[3] Gallese V., Goldman A., *Mirror neurons and the simulation theory of mind-reading*, Trends in Cognitive Sciences, Vol 2., 12. 1998.

[4] Hirsh K, and Bruer T. J., *The Brain/Education Barrier*, Science, Vol 317, 2007.

[5] International Organization for Standardization, 1999. *Human-centered design processes for interactive systems*. ISO 13407:1999.

[6] International UNESCO - *Creativity Workshop Toys for Children's rehabilitation*. http://www.spielmittel.de Access on Dec 20, 2013.

[7] Willis J., *Which Brain Research Can Educators*

Trust?, Phi Delta Kappan, Vol. 88, No. 09, pp. 697-699. 2007.

[8] Plan toys, *Mom made toys,* https://www.facebook.com/mommadetoys Access on Dec 20, 2013.

[9] Thomas K., Jonathan L., and Tom P., *The Art of Innovation Lessons in Creativity from IDEO, America's Leading Design Firm*, Crown Business, 2007.