



# Construction and Design Activities through Logo based 3D Microworld

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## Abstract

*Physical construction kits equipping motor or motion sensor and connecting Logo programming with traditional LEGO bricks have been actively introduced in recent years. Activities that utilize such physical construction kits may provide students with learning experience which engages them with creative thinking and problem solving. However there are some practical and physical limitations when using such kits in education due to their expense, weight and volume. This research would introduce constructionism based activities that utilize LOGO based 3D representation system (Cho et al., 2010) to construct mathematical creative artefact by expressing construction kits like LEGO bricks and Soma cubes with semi-formal symbolic expressions. We conducted a creativity contest utilizing semiotic symbols based on turtle metaphor and Web 2.0 educational platform, and we would report its educational implications.*

## Keywords

Mathematical activities, 3D representations, creative artefact, semiotic symbols, turtle metaphor

## Introduction

Spatial ability, as one of the important factors of human intelligence, is a cognitive function that is often used in various academic areas like mathematics, architecture and medical science as well as in our daily life activities like driving and swimming. Developing spatial ability is one of the major objectives in math education; therefore elementary school's math curriculum in Korea includes 'building block' which deals with 3D objects, and building blocks and soma cubes are often used as construction kits. However, it is still challenging to visualize 3D objects on a 2D paper and also physical limitations in using such kits are followed. Thus, a technology environment where students can construct and visualize objects is required in order for them to explore 3D objects.

Logo constructs geometrical objects with 'forward' and 'rotate' commands and this shares a fundamental philosophy with LEGO bricks which build a variety of 3D objects with basic blocks. Based on the basic ideas of LEGO, Cho et al. (2010) designed a representation system in a virtual microworld<sup>1</sup>, which constructs 3D building blocks as LEGO bricks do. This is composed of

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<sup>1</sup> Cho et al.'s 3D representation system (2010) is implemented in JavaMAL Microworld and the website address is as follows: <http://www.javamath.com>



simple symbols which elementary school students can learn easily by overcoming the problems occurred in the existing 3D Logo and minimizing the difficulty of program languages. That is, turtle symbols that construct 3D blocks consist of s (moving forward), L/R (turn left/right) and u/d (moving upward/downward) by using turtle metaphor. An example of constructing 3D objects with these turtle symbols is shown in Figure 1.

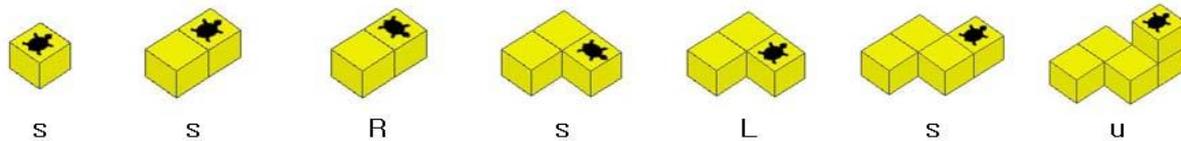


Figure 1. Logo-based 3D Representation System

Coming back to LEGO again, more advanced products including LEGO/Logo, programmable bricks and LEGO's WeDo have been recently developed by connecting Logo programming with traditional LEGO bricks (Resnick et al., 1996). This is to enable students to go through hands-on learning experience that actively engages them with creative thinking, team work and problem-solving skills by merging computer programs with traditional static LEGO bricks or equipping dynamic motor or motion sensor.

Based on Cho et al. (2010)'s 3D representation system, we will introduce activities that can be learned through design as constructing construction kits like building blocks, soma cubes and LEGO bricks dynamically and expressing them with semi-formal symbols in a virtual environment, and will study educational implications that can be found in such activities.



Figure 2. LEGO's WeDo

## Activities Engaging Mental Construction thru Physical Construction

We conducted a creativity contest where students build virtual LEGO bricks in a virtual environment using 3D representation system developed by Cho et al. (2010).<sup>2</sup> This contest was based on the constructionism - knowledge is constructed in the context of building personally meaningful artefacts in a media environment (Kafai & Resnick, 1996). The contest lasted for one month including 3-week preparation and 82 students ages 12 to 13 participated. During the 3 week contest preparation period, students learned turtle symbols that construct basic blocks, angle adjustment commands (ddv, rrv), spring command (e) that orders a straight-line motion and engine command (E) that orders a rotary motion through online video lectures, texts and JavaMAL Microworld screens. Then, they were required to submit a given task every week by using symbols and commands learned. During the last one week after the preparation period was over, students submitted their own creative artefacts by applying all commands learned and all tasks previously submitted. In all tasks and the final artefacts, all commands used and explanations were required to be included. We also encouraged communication among students by posting all tasks in the internet. With a theoretical background, we would study educational implications shown in the contest activity by looking at artefacts students submitted.

<sup>2</sup> The creativity contest was conducted in the website below where JavaMAL Microworld is in.  
<http://mentoring.snu.ac.kr/siheung>



### 1. Creative Thinking through Design

Activities that make a certain object as instructed in the manual in physical construction like LEGO can be ‘hands-on leaning’ or ‘leaning-by-doing’, but they cannot be learning-through-designing (Resnick & Silverman, 2005). Design tools should enable people to design, create and invent things (Papert, 1980). While preparing the contest, it was observed that students as ‘designers’ gradually developed their own artefacts in a creative way as they designed and created their objects. For example, the second task was to make artefacts by using engine command (E), which orders rotating. Figure 3 shows one student’s outcome after he learned basic commands of building blocks and engine command (E). This student made a ‘wind generator’ in ① by applying a pinwheel which was a initial task and evolved it to an ‘advanced wind generator’ in ②. ③ are symbols that construct ①, and ④ and ⑤ are student’s explanation on his artefact ① and ② respectively.

- ④: It’s a wind generator applied from a pinwheel, the initial task. It’s simple and easy, isn’t it?
- ⑤: This is an advanced wind generator. Doesn’t it look a bit complicated? It is amazing I could make it that complicated even if it was my first try.

While ① is a simple wind generator which use four engines only, ② is evolved from ① and turns out to be an ‘advanced wind generator’ in which thirty engines run complexly. Observing changes of the artefact from ① to ②, we suppose engine command (E) that orders dynamic action motivated and stimulated him to think creatively. As the student performed tasks in different stages, he was able to complete a more creative and well-made artefact and admired his own work. This learning environment not only engages learners in composing artefacts, but also encourages them to explore the ideas underlying their constructions.

### 2. Problem Posing and Problem Solving through Interaction

Hoppe at al.(2005) mentioned workspaces which can share visual objects provide a new channel on interaction by encouraging communication among people. The environment where the creativity contest held is a semiotic microworld (Cho et al., 2011) expressed in both ‘visual object’ and ‘semiotic symbols’ and this helps us understand learners’ thought process of how visual objects are constructed through the symbol structure. In addition, learners can reflect on their thought by observing the visual object outcome resulted from the symbols that they enter and also can correct their errors by manipulating symbols. The following case shows the process how one student who made a globe solved the problem posed by her mentor and peers – Earth's axis is tilted 23.5 degrees.

Ahn(peer): The earth's axis is tilted 23.5 degrees.

Lim(learner): Sorry, but I’m still having a trouble with angles. If I put ddv=23.5 as a command, then I cannot make a globe. Help me...

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Yang(mentor): Please check the hint given on the bulletin board.

Lim(learner): Wow, great. Thank you

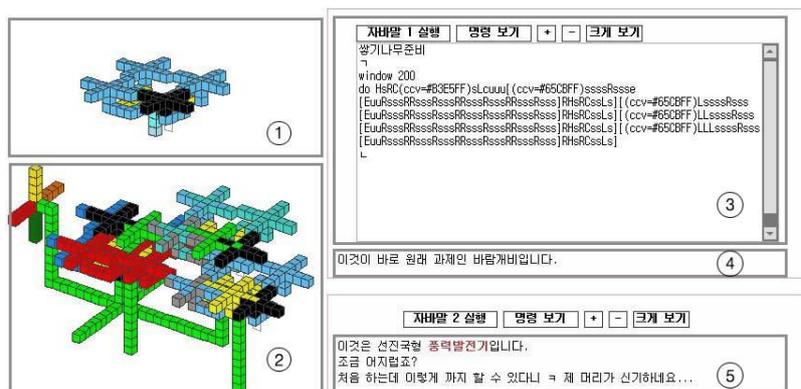


Figure 3. Learning through design



## Theory, Practice and Impact

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Wan(peer): Now, the globe rotates perfectly.

Duck(peer): Could we see the angle of 23.5 degrees?

Spongesong(peer): It's just like a real globe.

Yang(mentor): You couldn't make a perfect globe because you used m and o as commands. Actually, the commands you used were overused and this caused some facets to be overlapped. Only 36 times is enough to make a perfect globe. Do you know why? I'll leave this question as your homework. I also see you used the command - do (ccv=#DCDCDC)RRs[>s>s>s>s>s>s>s >s>s>s>[dd]suu[s]uRRsssds]RRsss- to make this axis. What do you need to do to make this axis symmetric?

Lim(learner): Thanks. \*^^\*

Lim(learner): I've got the answer to the problem. It's because I set rrv as 5 degree, if I rotate it 36 times, it turns out to be 180 degrees and consequently I can make a circle.

In the case above, we were able to observe 'affective expressions' like "The globe rotates perfectly." and "It's just like a real globe" as well as 'cognitive consideration' on angles and number of commands to tilt Earth's axis occurred to the students. The virtual microworld here works as an educational platform where learners can create, share and correct their artefacts by feedback and we regard it as a learning environment where learners pose problems in the context of the artifacts that they created, and solve them cooperatively.

### 3. Cognitive Thinking through Semiotic Symbols

Shaffer & Clinton (2006) introduced the concept of 'toolforthoughts' for the close reciprocal relation between tools and thoughts. In this ontology, there are no tools without thinking, and there is no thinking without tools; thus there are only toolforthoughts, which represent the reciprocal relation between tools and thoughts that exists in both. That is, moving forward from continuous reciprocal relation between tools and thoughts, they removed the distinction between the two and considered human cognition as something that works together with 'toolforthoughts'. We were able to find some examples of 'toolforthoughts' - symbols that students learned for the contest actually worked as a cognitive thinking tool.

'[ ]', one of the commands that students learned, was created to get rid of the step for turtle to go and come back to a certain point like the repeat mark in music. Turtle remembers its position and direction in '[', takes actions according to the given commands between '[' and ']' and comes back to '[' when ']' is commanded. Figure 4 shows an example of student's artefact that used a '[ ]' command. The student made one car wheel that can be created with the same structure of symbols. Then he created a symmetric command language using direction change as in ① and made the command language short by using double '[ ]' in the command. This shows '[ ]' symbol became toolforthoughts as this student's cognitive thinking tool to simplify the command language.

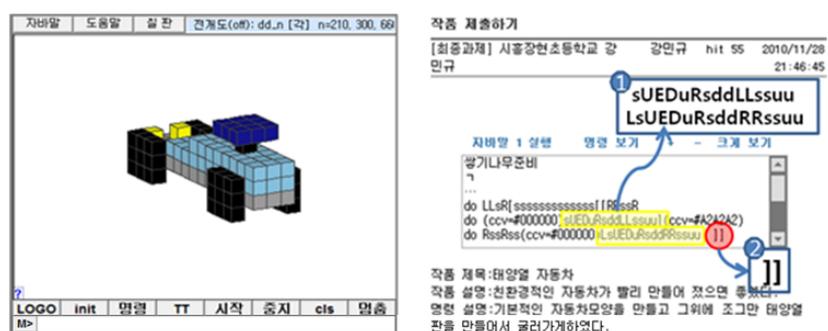


Figure 4. Usage of symbols as construction and thinking tools



## Closing Remarks

We examined the activities to make ‘dynamic LEGO bricks’ through semi-formal symbolic expression based on turtle metaphor in a virtual microworld. In the activities, students were able to become designers who design and create their own objects by using basic blocks that construct 3D objects and symbols that enable the objects to make dynamic motions. In addition, the virtual environment worked as a Web 2.0 educational platform where learners could create and share their own artefacts and receive feedback on them. Learners in this environment also could pose any problems naturally and solve them in the context of artefacts created by them. Finally, as a cognitive thinking tool, semiotic symbols that construct an artefact became a ‘toolforthoughts’ through manipulation process.

As one who lives in France may pick up French naturally (Papert, 1980), the virtual microworld became a ‘playground’ which engages learners with creative thinking, problem posing, problem solving, and cognitive thinking. It can be further studied how concrete experience that constructs 3D objects with semiotics symbols affects educational situations like spatial ability or algebraic symbol introduction in an affective and cognitive way. Furthermore, rather than stopping this activity as a one-time event, it would need to be linked to advanced education that can ‘learn’ and ‘inquire’ and thus be resulted to an environment where we can practice ‘Low Floor, High Ceiling and Wide Walls’ (Resnick & Silverman, 2005).

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