# Using Embodiment with LEGO Robotics to Enhance Physics Understanding in Elementary School Students

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**Abstract**: Elementary school students were taught to use LEGO NXT Mindstorm, a programmable reconfigurable robot, to observe and learn abstract physics concepts. Students were asked to use instructional embodiment to help programming LEGO robotics in a series of activities that incorporate different physics concepts including force and mass, speed and distance, and friction. The goal of this study is to examine whether embodied experience learned in programming a robotic Agent can be transferred and used as a tool to understanding and build better mental representation of physics concepts for elementary school students.

## Introduction

Our research team is currently working with elementary school students every Friday afternoon over a ten-week period on improving their understanding of abstract physics concepts from embodied experience with LEGO robotics. A form of embodied experience was developed as the underlying concept of our classroom instruction. Transferrable embodiment, or using embodiment experience learned from instructional embodiment as a tool in learning new concepts through an Agent, was developed and implemented in this study.

The embodied experience in this study was conducted through two forms of instructional embodiment concepts: direct embodiment (DE), which is the physical reenactment of the designed scenario, and imagined embodiment (IE), which is the mental reenactment of the designed scenario (Fadjo, Lu, & Black, 2009). Students in the embodied experience will physically and mentally act out given activities before programming LEGO robotics to execute these actions. In performing these activities, LEGO robotics become robotic Agents that demonstrate different physics concept to students.

By having the students exposed to embodied experience in programming robotic Agents, we propose that student will transfer this embodied experience to their observation of the physics concepts displayed by robotic Agents and form better understanding and mental representations. The effect of instructional embodiment and Agent learning on improving students' learning are provided. Implementation of embodiment in a $5^{th}$ grade classroom is presented. Results and analysis from the experimental data are pending while the anticipated results are presented.

## Instructional Embodiment

In recent years, cognitive scientists began to examine how mind and body work together to form better understanding through embodied cognition in different context and settings. Grounded/embodied cognition is becoming increasingly important in cognitive research and theory (Barsalou, 2008). In an embodied environment, students interact with their environment in the learning process through visual, auditory, or haptic channels. When their perceptions from these channels are in agreement with their understandings of the knowledge, they will learn better and faster. Glenberg and Kaschak (2003) found in their study that people response faster when their action responses are in agreement with their text responses.

Though embodied cognition has been implemented in many different forms (e.g. direct-manipulation animation and haptic channel (Chan & Black, 2006), haptic feedback and physics learning, social cognition and relationships (Semin & Cacioppo, 2007), domain knowledge with experts and embodiment (Beilock & Holt, 2007), and emotion and affect (Clore & Schnall, 2008; Barrett & Lindquist, 2008; Winkielman, Niedenthal, & Oberman, 2008), we choose to adopt instructional embodiment, and more specifically direct and imagined embodiments, as our grounding theory in providing students with embodiment experiences. DE and IE have shown strong evidences in helping students' programming skill by physically and mentally enact the functions and behaviors in the video games they have designed (Fadjo, Lu, & Black, 2009). By using DE and IE, students are left with a strong impression on the effectiveness of embodied experience.

**Agent Learning**

Agents are strong instructive tool that can take on many different forms, and different forms of Agent can help learning in different ways. Pedagogical Agent provides instant and complete information when needed. Teachable Agent helps students understand the system of concepts by constructing a concept map for their avatars (Schwartz et al., 2007). Reflective Agent helps students learn by specifying propositional, functional, and procedural knowledge to the avatar (Bai & Black, 2005). By choosing an appropriate Agent, students can learn different concepts quicker and better.

We used robotic Agents in this study because physics concepts can be best demonstrated by having a robotic Agent perform different designed activities. By having a robotic Agent as an avatar for student, we can have the robotic Agent perform many tasks that might otherwise be harmful to students. For example, a robotic Agent can demonstrate the devastating effects of crashing into a wall at full speed, a task that can produce unwanted results if performed by students. In addition, LEGO robotics offers students the environment and opportunity to observe abstract concepts through the use of tangible, hands-on objects (Druin & Hendler, 2000).

**Participants**

Our participants consist of fifth graders in an urban public elementary school. According to the results from pretest, some of the students have had some experience working with LEGO robotics. Most of the students display some interests in learning science but having low confidence in doing so. The students are randomly divided into two groups: a control and an experimental group, with six students in each group.

**Procedure**

The duration for each session is approximately two hours. During the first two sessions of our program, we introduced the LEGO Mindstorm robot to our participants. They were asked to build a basic LEGO NXT Mindstorm robot with another student according to the instructions in the manual. They also had the opportunity to create simple NXT programs so that they would become more familiar with programming in NXT Mindstorm. An example of a beginner NXT program would be to make the robot move forward for a certain amount of time they have designated. We gave the students a pretest testing their knowledge on three key concepts in physics: force and mass, speed and distance, and friction. We also conducted a survey on their background with physics and prior experiences with LEGO robotics.

In the next session, we used a demo robot to introduce NXT sensors to our students and asked them to build a Tribot that included two sensors: touch and light sensors. Following demonstration, students will be given adequate amount of time to finish building the Tribot with help from teachers. Students are then asked to participate in a "bowling competition," which is a series of hands-on activities we have designed for students to work on the rest of the program. Through the activities, students will investigate, learn, and apply the three physics concepts.

In part one of the bowling activity, students will be asked to program the robot so that it moves at a designated power level and stops until it hits a ball. The ball will roll for a certain distance. Students are asked to measure the distance of the ball and record it on their worksheet. In the second round, students will increase the power level in their program and perform the same activity. They are asked to observe what happens to the distance when the power level is increased. In part two of the activity, another ball of a different mass will be used and students will again measure the distance and compare that with the first type of ball they used. Students are required to answer related questions on their worksheet. They will observe the relationship between force and mass.

Eventually, they would find that the greater the force placed on an object, the greater the change in motion. Furthermore, the more massive an object is, the less effect a given force will have upon the motion of the object ("Force and Motion," 2009). In part two of the activity, students will test the identical program of pushing the two types of balls with different power levels but this time on another type of surface: the rug. They will observe the effect of friction on the motion of the balls and what kind of difference it makes on the distance.

During the activities, students in the experimental group will be asked to imagine themselves as the robots and move their own bodies according to the instructions given for the challenges. They will then program the robots to perform related movements. While they are programming the robots, they are also encouraged to imagine the robots' movements. Therefore, in part one of the activity, students in the experimental group will hold the ball in their hands, roll the ball with a certain force, and then observe what happens. In the second round, they will hold the other type of ball in their hands and physically feel the difference between the two types of balls used. They will see and feel the difference between the mass of the two objects used. In part two of the activity, students will roll the two types of spheres on the rug, just like what their robots would do. They will then observe the effect of friction on the motion of the objects. On the other hand, students in the control group are asked to sit in their chairs while receiving instruction regarding the bowling competition and programming the robots. After they have finished programming the robots, they are asked to test their program out with their robots.

After treatment, students in each group will be given a posttest with questions that we have created based on the science concepts introduced in the activities. In addition, participants will be asked to draw diagrams of their understanding of each physics concept. Finally, they will be interviewed to explain their understanding of each physics concept. During their explanation, we will video tape and analyze it to find out how their mental representation looks like by observing their hands gestures and words.

## Anticipated Results

We expect to see significant differences between the two groups in the learning and understanding of physics concepts in the posttest results as well as their drawings of their interpretation of each concept learned in the activities. We anticipate that the experimental group will have a better understanding and produce more concrete diagrams of each physics concept. In addition, we expect the students with the embodied experience to provide better verbal explanation and more meaningful gestures during the interviews.

## Conclusion

The results we expect to find from this study provide evidence that embodied cognition enhances students' understanding of science concepts by helping them build better mental representations. We also expect that learning with embodied experience can increase students' motivation in learning science with LEGO robotics. In addition, we believe that the results from the experiment can help educators in designing science curriculum and instructional materials for elementary school students.

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