Robotic and virtual world programming labs to stimulate reasoning and visual-spatial abilities

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Abstract

The individuals’ cognitive skills, academic performance and their relationship with programming of robots or virtual learning environment is a topic of particular interest in the area of human-robot interaction. This paper presents a pilot study performed on a group of 36 lower secondary school students involved in a 32-hours laboratory based on the combination of LEGO Mindstorm NXT and Microsoft Kodu Game Lab (KGL) and aimed at programming first a robot and further a more complete virtual world based on a narrative-designed scenario. The findings of the research will be discussed in the light of the effectiveness of using robotics and virtual world programming as a meaningful and playful learning environment for improving cognition in children.

Keywords: Robotics; virtual worlds; visual-spatial working memory; programming learning; playful learning environment.

1. Introduction

The use of robotics kits in primary and secondary education gives children the opportunity to experiment science, technology engineering and mathematics (STEM) concept in integrated curriculum or extracurricular activities (Kee, 2011). On the other hand, the use of software for designing and developing educational virtual worlds provides children with the freedom to image and create their amazing virtual world defining the environmental constraints (surface geology, vegetation, settlements) inhabits (characters, animals) objects (buildings, vehicles), and interactions overcoming the limits of using concrete artifacts in a real word. Kangas (2010) suggest us that robotics and virtual worlds immerse children in a playful learning environment promoting imagination, creativity, narration, thinking at different level of abstraction and collaborative co-creation. In the constructivist framework (Harel & Papert, 1991), robotic and virtual interfaces are considered powerful tools for learning concepts about Mathematics, Computer programming, and Physics (Resnick et al., 1996), for improving visual-constructive abilities, reasoning and problem-solving skills (Caci & D’Amico, 2002; Caci, D’Amico & Cardaci, 2004) and for enhancing narrative and paradigmatic thinking (Caci, D’Amico & Cardaci, 2007).

The present study uses LEGO Mindstorms as robot kit and the recent Kodu Game Lab (Fowler et al., 2011) as software tool for designing robots and virtual worlds. It is focuses on the cognitive processes and academic skills involved in the building and programming of a robot and in the designing and development of real and 3D fictional worlds.
world. The children are so engaged in three follow-up creative collaborative activities: creation of a story; building of a robot scenario with the LEGO kit; designing and programming of the virtual world with KGL tool. Thus, allow children to experiences three different ways of thinking: a narrative mode where children were advised to image a coherent story-line adapted to a real or virtual scenario. They were asked to imagine a real or fictional world with a robot/agent as protagonist and other environmental features or characters. They are also invited to think about differences of environmental constraints using LEGO kit and KLG tool. Moreover, children experience a concrete thinking (Harel & Papert, 1991) when they practices both with bricks, sensors, servomotors, central processor unit, input/output channels of LEGO kits and the real environment in which the robot interact. Finally, they experience a phase of abstract thinking interacting with virtual objects of KGL tool.

Using LEGO children assemble the bricks, motors and sensors (e.g., touch, ultrasonic, or light) for define the structure of the robot; create tracks for provide the path to be traveled; program the brain of robot (a programmable microcontroller-based brick named NTX) for the movements of robot, interactions with elements, detection of obstacles using a visual programming language.

Kodu Game Lab allows children to program a virtual world defining more complex scenarios: for example a rover to the discovery of marts; complex movements and interactions between characters and objects. Defining type of terrains, adding mountain, volcanoes, lakes, adding funny characters (e.g. Kodu, cycle, boat, fish), environmental elements (trees, apples, rocks clouds), paths (streets, enclosures, walls) city elements (houses, factories, huts, castles) are some of interface options provided by the system.

Although the literature about KGL is quite recent, first studies on Kodu have highlighted that its tale-based programming language is particularly easy to use also for novice students (Chiazzese & Laganà, 2010; Stolee & Fristoe, 2011), compared to textual language models used by Alice (Cooper, Dann, & Pausch, 2000), Greenfoot (2012) and Scratch (Maloney et al., 2004).

1.1. Purpose of this paper

Although the use of educational robotic and virtual word guide the experiential learning laboratory (32-hours), the purpose of this study is to establish the degree to which individuals’ cognitive and academic abilities are related to educational activities based on robotics, using a sample of secondary school students. It is specifically aimed to verify whether individuals with high scores on questionnaires that measure logical reasoning abilities, visual-spatial working memory and attention are more proficient in programming LEGO robots and KGL virtual world. It is also aimed at clarifying the role of academic abilities such as reading comprehension, arithmetical and geometrical problem-solving competencies in the development of LEGO/KGL programming skills. Furthermore, the study tries to establish whether educational robotics laboratories based on LEGO/KGL tools are effective for the enhancement of the same cognitive and academic abilities.

2. Method

2.1. Participants

The sample consisted of 59 secondary students of years old, attending their first year at two Secondary Schools (i.e. Scuola Media “Silvio Boccone” and Istituto Comprensivo “Michelangelo Buonarroti”) in Palermo (Italy). Participants were casually assigned to experimental (22 males and 14 females) and control group (18 males and 15 females). Children of the experimental group (EG) followed the LEGO/KGL robotics laboratory described below. Children of the control group (CG) followed the regular school activities.

2.2. Measures

A pre-post-post test design method was adopted. During the pre/post-test phases the cognitive abilities and academic performances of EG and CG were measured using the following questionnaires:
Eight syllogistic and conditional reasoning tasks, drawn from SAVIO (Automated System for the Evaluation of Operator Intelligence), developed by D’Amico, Cardaci, and Guarnera (2002). PML working memory battery (D’Amico & Lipari, 2012), aimed at measuring phonological and visual-spatial working memory, executive functions (shifting, updating, inhibition), rate of access to long term memory and speed of processing. The PML consisted of 19 tasks. The MT Reading Comprehension tasks (Cornoldi & Colpo, 1995), requiring children to read a narrative and an informative passage and to answer to 15 multiple-choice questions for each passage. Two arithmetical problem solving tasks and one geometrical problem solving task.

All the questionnaires were administered to participants by a team of trained psychologists in a classroom setting. Moreover, during laboratory the programming skills of children were assessed using two questionnaires (LEGO-Q and KGL-Q) respectively aimed at examining the acquisition of concepts about fundamentals of LEGO and KGL interfaces, and their programming rules.

2.3. The LEGO/KGL laboratory

After the pre-test assessment, children of the EG were involved to an experiential learning laboratory with LEGO and KGL tools. The laboratory consisted of eight four-hours sessions and was performed during the curricular school time. Also two researchers, two operators expert in robotics and the regular teacher participated to each laboratorial session.

Four sessions were based on LEGO robotics activities. First, children familiarize with robotics artifacts, watching movies of fantasy and real robots (e.g. Transformers, AIBO, RunBot). The movies were used as frames to start circle time discussions about scientific concepts related to Biology, Physics and Mathematics that are scaffold by robotics artifacts. For instance, the notion of brain, mind, sensory-motor apparatus, velocity, and light spectrum were introduced to participants using robots functioning as a model. Successively, in order to let children skilled with LEGO robotic kit, they were invited to classify all the LEGO bricks according to their functionality. Then, they built a small-mobile robot, following the instruction provided by the LEGO manual. After building their robot, children were trained with LEGO programming interface. Moreover, they were invited to create a narrative scenario (e.g. a script) for the robot behavior and to build a physical environment (i.e. the arena) using pasteboard, colors, modeling paste and other materials. Finally, participant realized the programming algorithms for adapting the robot to the created environment and completed the LEGO-Q questionnaire to verify the acquisition of LEGO programming skills.

Four sessions were based on KGL virtual world activities. Initially, children acquired the functionality of the Xbox controller for interacting with KGL interface and explored some illustrative virtual worlds. Next, they designed and realized their own environment, choosing terrains, mountains, lakes, and specific characters. Children were then trained to program the virtual world using appropriate rules (a rule in KGL is composed by a when-do tile) and to reproduced on KGL the narrative scenario previously realized with LEGO, enriching it with all elements and additional features available in KGL. Finally, participants were involved in collaborative programming sessions, and were then presented with the KLG-Q questionnaire aimed at verifying the acquisition of KGL programming skills.

2.4. Data analysis

To identify the possible relations between variables, Pearson correlation coefficients were calculated. In order to examine the effectiveness of laboratorial activities for the improvement of cognitive and academic skills, a series of 2X2 repeated univariate ANOVA with two levels of the between-subject factor Group (EG and CG) and two levels of the within-subject factor Time (Pre-test and Post-test) was performed on the individual scores obtained by children in experimental and control group, in each of the cognitive and academic tests.
3. Results

Results at Pearson’s product-moment correlation tests showed that deductive reasoning skills ($r=.72; p<.01$) and speed of processing visual targets are related with LEGO-Q scores ($r=.45; p<.05$). Scores in Visual-spatial working memory ($r=.49; p<.05$) and in updating executive function ($r=.46; p<.05$) are associated with KGL-Q scores. Reading Comprehension scores are correlated both with LEGO-Q ($r=.66; p<.01$) and KGL-Q scores ($r=.48; p<.05$), whereas Geometry problem-solving scores are related with LEGO®-Q scores ($r=.60; p<.01$).

The series of ANOVA showed an interaction Group x Time revealing that children in EG improved significantly their visual-spatial working memory score compared to the CG ($F_{2,43}=4.05; p<.005$).

4. Discussion and conclusion

The results of the present research confirm the importance of using educational systems based on robotics and virtual worlds to encourage the use of specific cognitive and attentive abilities as well as academic skills. Framed as learning environments based on problem-solving, LEGO Mindstorm and KGL tool involve, in fact, the subjects in a continuous interactive game. Searching for suitable bricks and building the robot, children exercise cognitive skills such as selective and focusing attention. As well, during the behavioral programming of the robot they are asked to exercise their logical reasoning. Similarly, developing virtual environments characterized by a scenario they apply their visual-spatial memory skills: place the objects in specific positions, orient them in a three-dimensional space, have a sense of position, recognize and using the references of cardinal points in a 3D space, create paths, insert characters, and then programming their movement and interactions with objects in the virtual environment is, in fact, a useful exercise for the working memory. In addition, the stimulation of the narrative skills of each student, involved in the creation of the story and screenplay as a backdrop to the world and their avatar, complete the set of skills elicited by this environment. Individuals have the opportunity to create virtual worlds more complex and rich of functionality beyond the limits imposed by the artifacts and the real world. In addition, the combination use of the LEGO kit and the KGL tool has allowed subjects to experiment a metaphorical mental shift from a concrete form of thinking (manipulating concrete objects and taking account the real environment constraints) to an abstract form of thinking stimulated by the use of virtual objects in the virtual world.

Experiential laboratories like this, able to combine the robotic technologies with virtual environments and the increasingly sophisticated immersive technologies, offer students the opportunity to experience new ways of learning. Traditional teaching methods are pushing us towards a scenario of augmented reality teaching that goes beyond the boundaries of real and experience those virtual for building the educational environments of future.

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References


