Enhancing the Potential of Creative Thinking in Children with Educational Robots

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Abstract. This observational study analyzes the effectiveness of the non-humanoid robot Ozobot as interactive-tool for school- children to enhance their potential of creative thinking. Based on the socio-constructivist theoretical background, referring to the zone of proximal development and the socio-cognitive conflict, the study compares three experimental condition (Ozobot Single Work, Ozobot Pair Work, and Control Group) of a problem-solving task with a robot (programming the robot to perform a given route in a preconfigured labyrinth). 171 children (85 females, 86 males), aged between 9 (IV class) and 10 years (V class) of two central-northern Italy primary schools, participated in the study. Children were randomly assigned to one of the three group conditions. Results show that children who performed the task alone with the educational robot (Ozobot Single Work) significantly improved their potential of creative thinking, compared both to those who perform the task in pair with the educational robot (Ozobot Pair Work) and to the control group. No gender differences occur.

Keywords. Creative Thinking, Educational Robot, Children, Problem-Solving.

1. Introduction

Similarly to an expert partner providing a "scaffold" that allows the child to achieve an upper level within the zone of proximal development, an educational robot (properly programmed) can be seen as a technological artefact helping children in exploiting their potential of improvement in many skills [1; 2; 3].

Starting from these premises, this study aims to verify that using a non-humanoid robot Ozobot to do a problem solving task, improves the potential of creative thinking in 9-10 years old children. For this reason, the Widening Connecting Reorganizing Test (WCR) [4] was used, in the pre-test and post-test phase, in order to evaluate the children's potential of creative thinking. All children completed the test in class singularly.

2. The Potential of Creative Thinking: Widening, Connecting, Reorganizing

Conflicts between partners play an important role in the developmental process, specifically during problem solving tasks: as a matter of fact, in these tasks different

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points of view could lead to more creative or advanced solutions, as described in studies of socio-cognitive conflict [5; 6; 7] and divergent thinking [8; 9].

Creativity can be characterized by three great mental operations: widening, connecting, and Reorganizing [4].

Considering these assumptions, the WCR [10; 4] is structured in three consecutive section (9 items) corresponding to the identified skills:

- The ability to succeed in widening one's point of view, and the ability to produce many different ideas.
- The ability to combine different elements and to establish relationships going beyond appearances and similarities or superficial differences.
- The ability to de-contextualize the elements of a situation to grasp the properties useful for restructuring and changing perspective.

In the present study, in which an educational robot is used in a problem-solving task to enhance the potential of creative thinking in 9-10 years old children working alone or in pair, the WCR test was filled in twice by the children (all together in class room, but singularly), for the pre-test and the post-test phases. Creativity scores were calculated from 1 (less creative) to 4 (very creative), based on the answers' frequency of the target population: the less frequent the answer, the more creative it is and vice-versa, obviously considering its coherence and appropriateness with the task.

The following hypotheses were formulated:

H1. The use of the educational robot Ozobot significantly improves children's potential of creative thinking in both experimental conditions (Ozobot_SW → Single Work, and Ozobot_PW → Pair work);

H2. Children who perform the task in the Ozobot_PW condition significantly improve their potential of creative thinking compared to those of the Ozobot_SW condition.

3. Methods

171 children participated in the study, 85 females and 86 males. 79 children attend the IV class and 92 the V class of Primary Schools in northern Italy. Children were randomly assigned to the two experimental conditions and to the control group: Ozobot_SW (n=56; 25 attend IV class and 31 attend V class), Ozobot_PW (n=85; 42 attend IV class and 43 attend V class) and control group (n=30; 12 attend IV class and 18 attend V class).

3.1. Materials and Procedures

Ozobot is a tiny educational robot (just 2.5 cm tall) that is programmed to follow colored lines on a surface. Its movements can be coded by mean of color codes. In this study, children are required to code the moves of Ozobot, by coloring the blank spaces of a maze on paper (fig. 1) with the preset color codes, to define a path and complete the task.

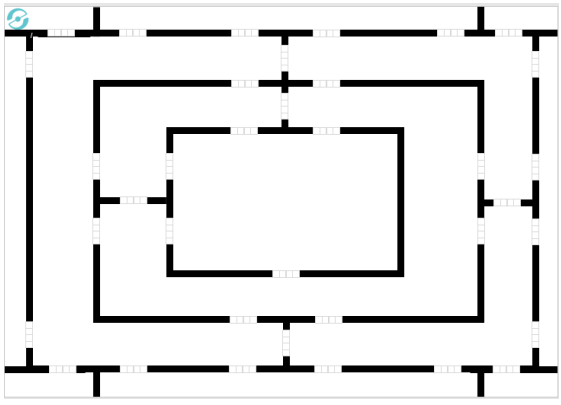

Figure 1: Example of a labyrinth task used in the experimental phase

The interaction between children and Ozobot is twofold: first, children use colors to determine the Ozobot moves, and second, by testing the coded path, children have a feedback about the correctness of the instructions given to the robot. In the Ozobot_SW condition, child completes the task singularly, while in the Ozobot_PW condition, children are required to complete the task in pair. The main difference is that, in the Ozobot_PW condition, having only 1 robot, the two children had to discuss for defining the color codes to use to make Ozobot move. No limited time was given by the researchers to complete the labyrinth.

Before (pre-test) and after (post-test) the experimental conditions, all children were individually evaluated with WCR Test. All the procedure took half a day per each class. Children of the Control group completed both the pre-test and the post-test before carrying out the same activity of the two experimental conditions.

4. Results

No significant differences were found between males and females, therefore the variable "gender" was excluded from the subsequent analyzes.

From the univariate analysis of the different WCR indexes emerges a significant interaction effect pre-post by work condition for the Widening Index ($F_{(2,168)}$=5.04; p<.05; Partial Eta^2=.057) and for the ACR total score ($F_{(2,168)}$=4.13; p<.05; Partial Eta^2=.047).

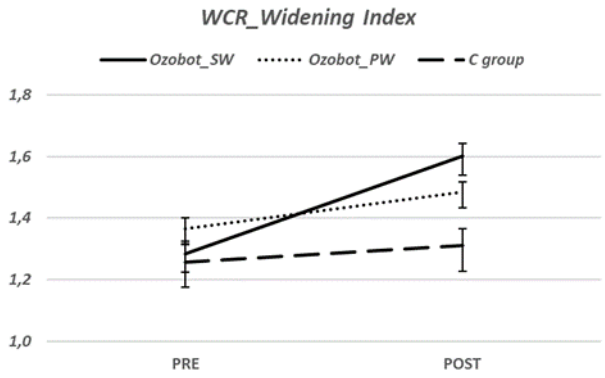

Figure 2: WCR Widening Index interaction between groups and pre-post condition

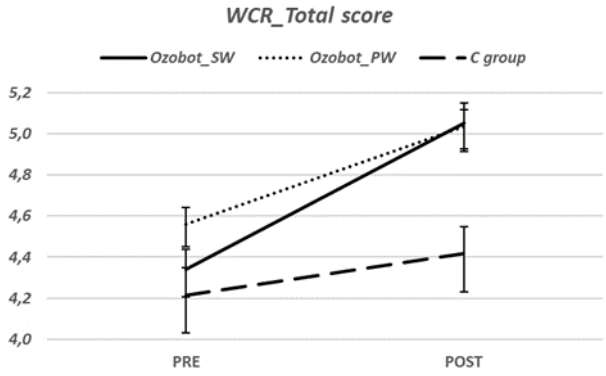

Figure 3: WCR Total score interaction between groups and pre-post condition.

In particular, as shown in fig. 2 and fig. 3, a steeper performance increase can be seen in the Ozobot_SW condition compared to the Ozobot_PW condition and to the Control group, both for the Widening Index (fig. 2) and the total score (fig. 3). No significant interaction effect pre-post by work condition was found for the Connecting Index nor for the Reorganizing Index.

For a descriptive purpose, new variables were calculated as pre-post performance differences in each WCR Indexes (post minus pre). The WCR's difference Indexes has

been used as dependent variables in an ANOVA and a post hoc multiple comparison with Bonferroni's correction was used to compare group's scores.

Results show that the performances in Widening Index of the subjects belonging to the Ozobot_SW condition improve significantly more than both the Ozobot_PW condition and the C group (difference =.26, SE=.098, $p<.05$). There are no differences between Ozobot_PW condition and C group. For the WCR total score Ozobot_SW condition show significant better performance from the C group.

5. Discussion

The main objective of this study was to analyze the effectiveness of the non-humanoid robot Ozobot as interactive tool for schoolchildren to enhance their potential of creative thinking, measured with the WCR test (Widening, Connecting, and Reorganizing). Even though the study have been carried out in ecological contexts (schools) that limited the possibility to have a full control of all the environmental variables influencing the situation (e.g. the attention of the children on the task; the presence of the teacher), significant and very interesting results can be highlighted.Considering the WCR's total score, H1 is confirmed in all experimental conditions, i.e. all groups show a significant improvement between the pre and post-test. Ozobot_SW condition shows the highest improvement, while the lowest characterizes the Control group, and the Ozobot_PW condition is in intermediate position with respect to the other two. However, the Ozobot_SW condition has a significantly higher improvement than the C group, while no differences exist between Ozobot_SW condition and Ozobot_PW condition. Thus, we could explain the result of the Control group as a habituation effect to the proposed activity.

H2 is not confirmed. A possible explanation could be that children working singularly were asked to do all the actions needed alone without the possibility to adjust to someone else's solution: thinking a solution (route), finding the correct codes, coloring the blank spaces of the labyrinth, checking the correctness of the solution adopted. Children that carried out the task in pair, on the contrary, show a sort of normalization effect [11] i.e. many times they distributed their actions so e.g., a child checked for the correct code while the other colored the labyrinth. In this way, they tried to avoid conflict rather than find the best solution to the task. As the socio-cognitive conflict is seen as one of the motor of the creativity, avoiding it by adopting a solution without reflecting and discussing on it did not probably allow those children that worked in pairs to develop in a more creative way their solutions (and their way of thinking in the post-test).

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