Using Educational Robot to Enhance the Potential of Creative Thinking in Children

Martina Benvenuti[1][0000-0001-8575-5047], Sara Giovagnoli[2][0000-0002-3252-8083] and Elvis Mazzoni[2][0000-0002-7258-5381]

[1] Italian National Research Council, Istituto per le Tecnologie Didattiche, Via de Marini 6 · 16149 Genova, Italy
[2] University of Bologna - Department of Psychology, Piazza Aldo Moro 90 – 47521 Cesena, Italy

Abstract. This research analyzes the effectiveness of the non-humanoid robot Ozobot as interactive-tool for school- children to enhance their potential of creative thinking. The study compares three experimental condition (Ozobot Single Work, Ozobot Pair Work, and Control) in a problem-solving task (programming the robot to perform a given route in a paper labyrinth) in 171 children aged between 9 and 10 years (85 females, 86 males). Results show that children who performed the task alone with the robot (Ozobot Single Work) improved their potential of creative thinking significantly compared with those who perform the task in pair with the robot (Ozobot Pair Work) and the control group. No gender differences occurs.

Keywords: Children, Zone of Proximal Development, Educational Robot, Potential of Creative Thinking.

1 Introduction

Human Robot Interaction (HRI) is an area that involves the analysis of human behavior in natural and artificial contexts [1]. Studies with preschool and schoolchildren have focused on child-robot interactions during computational thinking tasks [2], creative dance [3; 4], storytelling [5], learning English [6; 7] and scientific skills such as computer programming, engineering, physics and mathematics [8].

As suggested by Woods, Walters, Koay and Dautenhahn [9; 10], this specific field needs to be extended to other areas of application to have input deriving from the use of different research methods, such as develop creative potential and consequently creative thinking. Further, since researches on gender differences in creativity have highlighted controversial results [11; 12], the HRI could help to deeply understand any differences between females and males. Starting from these premises, and from those research that involves educational robot to develop the potential of creative thinking [13; 14; 15]; this research aims to verify that using non-humanoid robot Ozobot (Fig. 1) to do a problem solving task, could improve the potential of creative thinking in 9-10 years old children.

Fig. 1: Non-humanoid robot Ozobot Evo

2 Theoretical Background

2.1 The Potential of Creative Thinking in Children

The main theories regarding learning with robots are related to constructivism (knowledge is active and derived from individual experiences) [16], constructionism (learners construct mental models to understand the world around them) [17], and social constructivism (human development is socially situated and knowledge is constructed through interaction with others) [18]. Social constructivism, in particular, is central for the research as regards the concept of Zone of Proximal Development [19] that defines the child's potential development. This potential development is determined by the difference between what a child can do alone and what he/she could do with the adequate support of a more experienced child. In this process, conflicts play an important role, since in problem solving tasks different point of view could lead to more creative or advanced solutions, as described in studies of socio cognitive conflict [20; 21; 22] and divergent thinking [23; 24].

Divergent thinking is the central aspect of originality and consequently of the potential of creative thinking [15; 25; 26]. The divergent thinking is not a direct measure of creative thinking, but as it often leads to originality (and originality is the central feature of creativity), it is directly connected to the potential of creative thinking [27].

Based on these premises, this paper presents a research in which an educational robot is used in a problem-solving task in order to enhance the potential of creative thinking in 9-10 years old children working alone or in pair.

2.2 The WCR test

It is possible to identify three great mental operations that underline creativity.

Firstly, creativity comes from a widening of the mental field. If the individual is able to produce many different and unusual ideas [28], if he/she takes something existing and tries to change it [29], if he/she generates different solutions in order to identify at

least one that survives the evaluation [30], he/she has probably a wealth of mental elements that increases the probability of identifying, among them, one that leads to something new and appreciable. Thus, enlarging the mental horizon through the discovery or invention of new elements contributes to creativity.

Second, as outlined by studies in the field of divergent thinking and socio-cognitive conflict [7; 31], creativity emerges when relationships are established between very different realities [32] or even opposite [33]. From this perspective, the basic process of creativity are related to connecting mental fields usually considered distant or antithetical.

Thirdly, creativity develops when the mental field is reorganized, or through its internal restructuring [34], or through the application of an interpretative scheme usually applied to other situations that could produce a new vision opening new perspectives and meanings [35].

Widening, connecting, reorganizing can be interesting processes to assess the creative abilities of people. Considering this assumptions, the WCR test [15; 36] is organized in three consecutive section (9 items) corresponding to the three skills identified:

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

W = Widening (3 items). It is asked to choose one answer among alternatives that vary progressively from perfect conformity with the stimulus until the complete inconsistency (creative "inconsistency" not that could seem a nonsense but it is related to the removal of the common schemes of thought) with what the stimulus is in reality.

C = Connecting (3 items). It is asked to choose the elements to associate with the given stimulus among a list of possible answers.

R = Reorganizing (3 items). It is asked to choose an answer among possible alternatives that progressively vary from obviousness to unusual and curious situations. Sometimes the subject must choose, among different scenarios, that completing the initial scene and, based on this choice, invent a short story.

All items are made by visual stimuli - such as images of objects, geometric figures or scenes - and verbal stimuli, ranging from the presentation of single words to sentences. Moreover, all items avoid the effects of tiredness and boredom, support motivation, arouse curiosity and invite children to diversify their thoughts.

In the present study, the WCR test was used in the pre-test and post-test phase in which all children filled in the test in class all together but singularly. Creativity scores are calculated from 1 (less creative) to 4 (very creative) and it is based on the answers' frequency of the target population [15; 36]. This means that the less frequent answer is the more creative answer and vice-versa.

2.3 Research Hypotheses

Based on the previous assumptions, the following hypotheses were formulated:

H1. The use of educational robot Ozobot significantly improves children's potential of creative thinking in both experimental conditions (Ozobot 1-Child and Ozobot 2-Children);

H2. Children who perform the task in the Ozobot 2-Children condition significantly improve their creative potential and thinking compared to those of the Ozobot 1-Child condition.

3 Methods

3.1 Participants

171 children participated in the research, 85 females and 86 males. 79 children attend the IV class and 92 the V class of Primary Schools of northern Italy[1]. The children were randomly assigned to one of the three group conditions: Ozobot 1-Child, i.e. Single Work group (Ozobot_SW) (n=56; 25 attend IV class and 31 attend V class), Ozobot 2-Children, i.e. Pairs Work group (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). The regional ethics committee approved the research protocol and the parents of all subjects gave their informed consent. The research was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

3.2 Materials and Procedures

Ozobot is just 2.5 cm tall and thanks to a color sensor at its base it is able to "read" color codes. These consist precisely of a combination of three or four colors (green, blue, black or red) which, once "read", lead to an action such as speed or direction adjustment. Therefore, by inserting different sequences of colored codes it is possible to encode the movements of the robot and make it performs a specific path.

The research was carried out in the school that participated in the project. All the children were individually evaluated both with WCR Test in a pre-test phase (before the experimental activity) and in a post-test phase (after the experimental activity), and all the procedure took half a day per each class. Those in the Control group completed both the pre-test and the post-test before carrying out the same tasks as the children belonging to the Ozobot_SW group or the Ozobot_PW Group. In this way, the activity carried out with Ozobot could not have affected the results of the post-test.

In the Ozobot_SW condition, the child is required to complete a paper labyrinth to get a route to Ozobot (Fig. 2).

[1] http://www.indire.it/lucabas/lkmw_img/eurydice/quaderno_eurydice_30_per_web.pdf

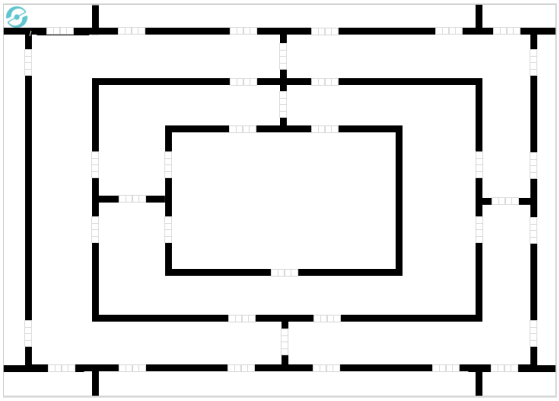

Fig. 2: example of a labyrinth task used in the experimental phase

Child had to color the blank space using the "color code reference chart" (Fig.3).

Fig. 3: Ozobot color code reference chart used in the experimental phase

In the Ozobot_PW condition, children are required to complete together a paper labyrinth by coloring the blank space using the "color code reference chart". The difference between the two conditions is that in the Ozobot PW the two children had 1 Ozobot thus they had to discuss and decide how to color blank spaces to make Ozobot move.

In both experimental conditions, children had the complete autonomy to choose and decide which colors to use and which Ozobot moves had to do. No limited time was given by the researchers to complete the labyrinth.

The interaction between children and Ozobot is twofold. First, children use colors to determine the Ozobot movements. Second, thanks to the robot's movements, children have a feedback about the correctness of their instructions.

3.3 Statistical Analysis

The data are analyzed by means of SPSS package version 23. The General Linear Model (GLM) for repeated measures is used to compare the pre-post performances in the different group conditions. The pre and post measures for the different WCR subscales (Widening Index, Connecting Index and Reorganizing Index) and for the WCR Total score have been used as repeated measures, the work conditions (Ozobot_SW, Ozobot_PW and C control group) has been used as independent variable.

For a descriptive purpose a pre-post difference variables for each WCR indexes were calculated and a multivariate analysis post hoc multiple comparison with Bonferroni's correction was used to compare WCR's Indexes pre-post difference between the groups.

4 Results

No significant differences were found between males and females ($F(4,166) = 1.08$; $p = .37$; Partial Eta Squared $= .026$), therefore the variable "gender" was excluded from the subsequent analyzes.

Results show a significant principal effect pre- and post- intervention ($F(4,165) = 14.19$; $p < .05$; Partial Eta Squared $= .256$) with a better performance obtained after the intervention (pre: $m = 5.46$; $SE = .011$; post: mean$= 6.04$; $SE = .013$). A significant difference was found between the general performances obtained in the three groups considered ($F(8,330) = 2.07$; $p < .05$; Partial Eta Squared $= .048$). Results shown a general better performance in Ozobot PW group ($m = 5.89$; $SE = .13$) compared with the Ozobot SW group ($m = 5.87$; $SE = .16$) and the Control group ($m = 5.39$; $SE = .22$). No significant interaction effect pre-post by group condition was found ($F(8,330) = 1.56$; $p = .135$; Partial Eta Squared $= .037$).

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 Squared $= .057$) and for the WCR total score ($F(2,168) = 4.13$; $p < .05$; Partial Eta Squared $= .047$).

As shown in fig. 4, a steeper performance increase can be seen in the Ozobot_SW group as compared to the Ozobot_PW group and to the C group, both for the Widening Index and the total score.

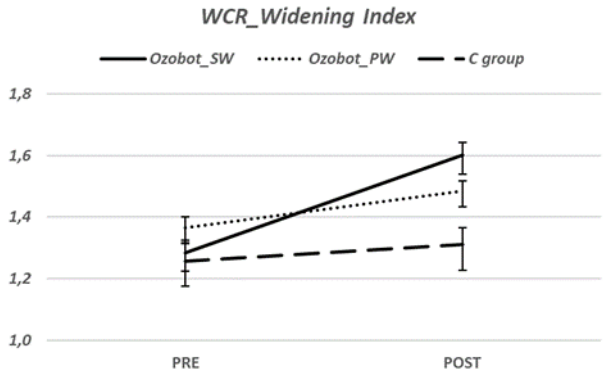

Fig. 4: WCR Widening Index interaction between groups and pre-post condition.

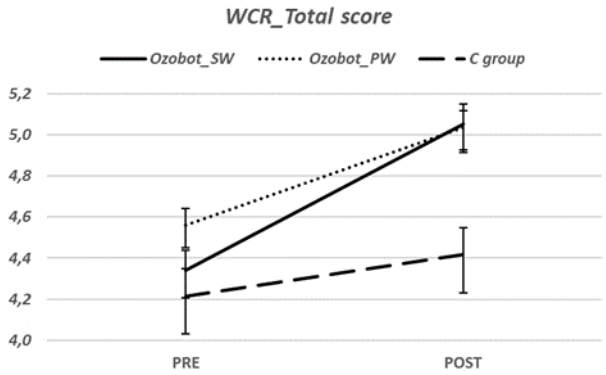

Fig. 5: WCR Total score interaction between groups and pre-post condition.

No significant interaction effect pre-post by work condition was found for the Connecting Index (F (2,168) =1.028; p=.36; Partial Eta Squared =.012) nor for the Reorganizing Index (F (2,168) =1.00; p=.367; Partial Eta Squared =.012). Although all the groups shown a better post-test performance, the resulting lack of interaction effect for the Connecting and Reorganizing Indexes, indicate a comparable slope increase (comparable pre-post performance increase) in the three groups.

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.

The results show that the performances in Widening Index of the subjects belonging to the Ozobot_SW group improve significantly more than both the Ozobot_PW group (difference =.20, SE=.075, p<.05) and the C group (difference =.26, SE=.098, p<.05). There are no differences between Ozobot_PW and C group (Diff =-.06, .09, p=1). For the WCR total score Ozobot_SW group show significant better performance from the

C group (difference =.51, SE=.14, p<.05) while no difference emerges between the Ozobot_SW and Ozobot_PW groups (difference =.23, SE=.18, p=.24) as well as between Ozobot_PW groups and C group (difference =-.27, SE=.17, p=.33).

5 Discussion

The main goal of this research has been to analyze the effectiveness of the non-humanoid robot Ozobot as interactive-tool for schoolchildren to enhance their potential of creative thinking measured by means of WCR test. The analysis has taken into account the difference between the pre-test and post-test in the WCR.

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 group shows the highest improvement, while the lowest characterizes the C group, and the Ozobot_PW group is in intermediate position with respect to the other two. However, the Ozobot_SW group has an improvement significantly higher than the C group, while no differences exist between Ozobot_SW group and Ozobot_PW group. Thus, we could explain the result of the C group as a habituation effect to the task.

The result of the Ozobot_PW group explains why the H2 is not confirmed. A possible explanation of the fact that children working singularly show the higher improvement could be find in the same task. Because they were alone to perform the task, they were asked to do all the actions needed: 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, many times have divided the actions to perform so e.g., a child checked for the correct code while the other colored the labyrinth. Indeed, the Ozobot_PW condition is not a classic socio-cognitive conflict situation in which children have two different point of views and they have to find a solution, but it is a collaborative situation in which children decided how to carry out the task. Thus, further research could use a real socio-cognitive conflict condition to create a situation of greater divergence thinking and verify the effect on development of children potential of creative thinking.

Further analysis are in progress on the same data to verify some differences between children of different age (9 vs 10) and different classes (IV vs V).

6 Acknowledgment

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Special thanks go to the students and teachers of "Circolo Didattico Cesena 2", for their participation in this study.

References

1. Dautenhahn, K. Socially intelligent robots: dimensions of human - robot interaction. Philosophical Transactions of the Royal Society B. Biological Science, 362(1480), pp. 679-704 (2007).
2. Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. Computers & Education, Vol. 72, pp. 145-157 (2014).
3. Ros, R., & Demiris, Y. Creative dance: an approach for social interaction between robots and children". In Human Behavior Understanding, pp. 40-51. Springer International Publishing (2013).
4. Ros, R., Coninx, A., Demiris, Y., Patsis, G., Enescu, V., & Sahli, H. Behavioral accommodation towards a dance robot tutor. In Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction, pp. 278-279. Bielefeld, Germany (2014).
5. Fridin, M. Storytelling by a kindergarten social assistive robot: A tool for constructive learning in preschool education. Computers & Education, Vol. 70, pp.53-64 (2014).
6. You, Z. J., Shen, C. Y., Chang, C. W., Liu, B. J., & Chen, G. D. A robot as a teaching assistant in an English class. In Advanced Learning Technologies, Sixth International Conference on pp. 87-91. Kerkrade, Netherlands (2006).
7. Mazzoni, E., & Benvenuti, M. A Robot-Partner for Preschool Children Learning English Using Socio-Cognitive Conflict". Educational Technology & Society, Vol. 18(4), pp. 474-485 (2015).
8. Benitti, F. B. V. Exploring the educational potential of robotics in schools: A systematic review. Computers & Education, Vol. 58(3), pp. 978-988 (2012).
9. Woods, S., Walters, M. L., Koay, K. L., & Dautenhahn, K. Comparing human robot interaction scenarios using live and video-based methods: towards a novel methodological approach. In Advanced Motion Control, 9th IEEE International Workshop on pp. 750-755. Istanbul, Turkey (2006a).
10. Woods, S. N., Walters, M. L., Koay, K. L., & Dautenhahn, K. Methodological issues in HRI: A comparison of live and video-based methods in robot to human approach direction trials". In Robot and Human Interactive Communication, The 15th IEEE International Symposium on pp. 51-58. Hatfield, UK (2006b).
11. Baer, J., & Kaufman, J. C. Gender differences in creativity. The Journal of Creative Behavior, 42(2), pp. 75-105 (2008).
12. Abraham, A. Gender and creativity: an overview of psychological and neuroscientific literature. Brain Imaging and Behavior, 10(2), pp. 609-618 (2016).
13. Johnson, J. Children, robotics, and education". Artificial Life and Robotics, Vol. 7(1-2), pp. 16-21 (2003).
14. Mikropoulos, T. A., & Bellou, I. Educational robotics as mindtools. Themes in Science and Technology Education, Vol. 6(1), pp. 5-14 (2013).
15. Pizzingrilli, P., Valenti, C., Cerioli, L., & Antonietti, A. Creative thinking skills from 6 to 17 years as assessed through the WCR test. Procedia-Social and Behavioral Sciences, Vol. 191, pp. 584-590 (2015).
16. Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J. J. A review of the applicability of robots in education. Journal of Technology in Education and Learning, Vol. 1(209-0015), p. 13 (2013).
17. Papert, S. Mindstorms: Children, computers, and powerful ideas. Basic Books, Inc. (1980).
18. Kim, B. Social constructivism. Emerging perspectives on learning, teaching, and technology, Vol. 1(1), p. 16 (2001).

19. Vygotskij, L.S. Interaction between learning and development. Readings on the development of children, Vol. 23(3), pp. 34-41(1978).
20. Doise, W., Mugny, G. The social development of the intellect. Oxford: Pergamon Press (1984).
21. Doise, W., Mugny, G., James, A. S., Emler, N., & Mackie, D. The social development of the intellect (Vol. 10). Elsevier (2013).
22. Doise, W., Mugny, G., & Perret-Clermont, A-N. Social interaction and the development of cognitive operations. European Journal of Social Psychology, Vol. 34(2), pp. 160-174 (1975).
23. Guilford, J. P. Traits of creativity. In H. H. Anderson (Ed.), Creativity and its cultivation. New York: Harper (1959).
24. Torrance, E. P. What is honored: Comparative studies of creative achievement and motivation. Journal of Creative Behavior, Vol. 3(3), pp. 149–154 (1969)
25. Piffer, D. Creative achievement, personality, and creative potential. International Journal of Anthropology, Vol. 26, pp. 145-165 (2011).
26. Runco, M. A., & Acar, S. Divergent thinking as an indicator of creative potential. Creativity Research Journal, Vol. 24(1), pp. 66-75 (2012).
27. Runco, M. A., & Acar, S. Divergent thinking as an indicator of creative potential. Creativity Research Journal, Vol. 24(1), pp. 66-75 (2012).
28. Guilford, J. P.. University of Southern California. American Psychological Association, 5, pp. 444-454 (1950).
29. Simonton DK. Origins of genius: Darwinian perspectives on creativity. New York: Oxford University Press (1999).
30. Johnson-Laird PN. The computer and the mind. London: Collins (1998).
31. Benvenuti, M., Piobbico, G., & Mazzoni, E. Robots and Socio-cognitive Conflict Enhance Wayfinding in Children. Annual Review of Cybertherapy and Telemedicine, p. 33 (2017).
32. Mednick, S. The associative basis of the creative process. Psychological review, 69(3), pp. 220 (1962).
33. Rothenberg A. The emerging goddess: the creative process in art. Science and other fields. Chicago: University Chicago Press (1979).
34. Wertheimer M. Productive thinking. New York: Harper (1959).
35. Schank RC. The creative attitude: learning to ask and answer the right questions. New York: Macmillan (1988).
36. Antonietti, A., Colombo, B., & Pizzingrilli, P. The WCR model of creativity. From concept to application. The Open Education Journal, Vol. 4(1), pp. 80-89 (2011).