Coding with me: exploring the effect of coding intervention on preschoolers' cognitive skills

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Abstract. In the last ten years, the topic of Computational Thinking (CT) has been gaining increasing attention from researchers in the education field. Starting from kindergarten, increasingly programming activities such as coding and educational robotics are proposed to enhance CT and some cognitive skills, such as problem-solving, spatial and reasoning skills. The most commonly used tools are the so-called tangible interfaces, such as floor-robots (e.g. Cubetto, Bee and Blue-Bot and others), through which children can interact with the object and learn playfully. Investigating the effects of CT activities on children's cognitive abilities is important to understand the impact in kindergarten and to comprehend in which developmental periods these activities might be most successful. The aim of the present study is that of evaluating the effect of a coding intervention, based on CT, through the use of the Cubetto robot, on the cognitive skills of 4-years-old children. The coding intervention included three sessions and required the manipulation of physical objects to plan and conduct a Cubetto journey. Results showed that children of the experimental group performed better than those of the control group in programming the Cubetto path after the intervention.

Keywords. Coding, Computational Thinking, educational robotic, cognitive skills

1. Introduction

In the last ten years, the topic of Computational Thinking (CT), such as a thought process that uses analytic and algorithmic approaches to formulate, analyze and solve problems [1; 2; 3], has been gaining increasing attention from researchers in the education field. In particular, several studies implementing coding and educational robotics activities in kindergarten found significant influence between CT and some cognitive skills, such as problem-solving, spatial and reasoning skills and short-term memory [4; 5, 6; 7; 8; 9; 10].

Thus, starting from kindergarten programming activities such as coding and educational robotics can allow children to become code-literate, that is to be able to read, write and think through the computer language and to be able to think in a computational way [11]. The most commonly used tools to sustain CT are the so-called tangible interfaces, such as floor robots (e.g. Cubetto, Bee and Blue-Bot and others), through which children can manipulate the object with which they are interacting and understand the activity they are performing step by step [9; 12]. Specifically, children are required to program

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the correct sequence of actions to achieve a specific goal, thus enhancing sequential skills that are recognized as very important for cognitive development since the early stages of kindergarten [8].

Moreover, in addition to the most current reflection on the use of digital media in education, literature has highlighted how the use of story-telling tasks promotes the development of narrative thinking and other relevant skills such as Theory of Mind and perspective-taking skills [13]. Story-telling tasks, based on a sequential logic similar to the programming language, can be used to support and integrate robotic programming learning in education.

Generally, in the field of computer technology, educational robotics activities are structured according to a playful approach and appropriate to the child's developmental phase [14; 15], thus sustaining independent learning and discovery [16]. Coding activities and educational robotics can be seen as real constructivist programming environments, in which children are encouraged to reflect on their thinking processes through activities in which abstract ideas are concretely and precisely conceived [17; 18; 8].

Moreover, in addition to stimulating the cognitive abilities of the single child, such as problem-solving, spatial skills, reasoning skills and short-term memory, the use of robotics in kindergarten promotes different types of learning, such as new ways of social interaction with peers and opportunities for social and cognitive development [15]. Furthermore, the use of educational robots can stimulate the potential development level that the child can reach through social support from more expert peers, teachers and educators, that play the role of real scaffolders [15].

Exploring the effects of CT activities on children's cognitive skills is important to evaluate the impact of their introduction at infancy school. This paper aims to contribute to this reflection, by exploring how instructional activities that teach the initial elements of CT by guided exposure to coding can boost the development of cognitive skills of 4-years-old children. The coding intervention included three sessions and required the manipulation of physical objects with symbolic meaning to plan and conduct a robot journey, thus stimulating the children visual spatial and story-telling ability.

2. Methods

2.1 Participants

The experimental study involved a sample of 40 children aged 4, attending three different kindergartens in the province of Milan, The children's parents received a detailed description of the study and expressed their written consent for their child participation to the research. All tasks selected were deemed appropriate for age of subjects participating in this experimental study and approved by the Ethics Committee of the Department of Psychology of Università Cattolica del Sacro Cuore of Milan.

2.2 Apparatus and Material

The children were divided into two groups: 1) an experimental group (N=20, 11 females) that followed the coding intervention and whose children were evaluated individually before and after the intervention; 2) a waiting list group (N=20, 10 females) whose children were evaluated at the same time but followed the intervention after the experimental group. The coding intervention lasted four weeks and consisted of three 60-minute laboratory sessions scheduled during the regular kindergarten day. It involved the use of Cubetto, an innovative tangible coding technology that facilitates young children's engagement with basics of coding, founded on the principle of visual programming (i.e. the child can design a route directly with his/her own hands without the use of a computer, yet it incorporates traditional play elements such as patterns, colour recognition and shape sorting). Specifically, children were assisted in defining Cubetto's orientation and the direction needed to reach a specific target throughout subsequent path episodes.

The assessment phase lasted about 20-25 minutes per child both pre (T0) and post (T1) intervention. Each child was invited to actively participate to the assessment sessions and was instructed to carefully listen to the instructions, ask questions when in doubt and perform the test according to his/her own skills. Specifically, the assessment included: an adapted version of Understanding of pictures stories test [19], used to assess the child's ability to reorder images with a predetermined sequence; the Children's Mental Transformation Task [20] used to evaluate the children visual-spatial abilities according to their cognitive development; an ad hoc task that involved the use of Cubetto, to observe what specific methods of achieving a target were used by the child during the task. Children involved in the test were asked to program Cubetto's path over the map using a keyboard in which they could insert coloured cards, where the different colours (green to go forward, red to turn right and yellow to turn left) represented the useful commands to move Cubetto on the map. Drawings were shown on the map that could be used to create educational stories or, as in this case, to construct coding paths to move Cubetto. The task involved the programming, by the children, three Cubetto paths for achieving a precise target on the Cubetto's map, previously indicated by the researcher through the description of a story divided into three parts. Following the preliminary instructions to perform the task, Cubetto was placed on a precise starting point on the map, equal for all, and the following three paths were narrated one by one to enable the child to focus on a single path. Each path started from the previously achieved end point . The final score of the Cubetto task ranged from 0 to 3: 1 point was allocated when the child was able to reach the target of the path. The total score is given by the sum of the three paths' points.

2.3 Results

To test the effect of coding intervention on children understanding of stories and visual-spatial abilities, we ran a 2 (groups) x 2 (pre- vs. post) repeated-measures ANOVA. The primary purpose of two-way repeated measures ANOVA is to understand whether there is an interaction between these two factors on the dependent variable. In this case, results did not show significant interaction effects both related to children ability to reorder images with a predetermined sequence [$F(1, 41) = 1.246$, $p = .27$] and to children visual-spatial ability [$F(1, 41) = .008$, $p = .93$]. Thus, after the coding intervention children did not significantly improve these abilities.

Furthermore, to test the effect of coding intervention on children abilities to program Cubetto to achieve a target on the map, we ran a 2x2 repeated-measures ANOVA with Cubetto task score as dependent variable. In this case, we found both a significant time effect [$F(1, 41) = 30.022$, $p = .001$] in both groups and a significant time x group interaction effect [$F(1, 41) = 9.825$, $p = .003$]. This means that both the experimental and control groups increase their abilities in programming Cubetto to achieve the goal, but children of experimental group performed better than those of control group.

3. Discussion

In this study we analyzed the effects of a coding intervention, through the use of the floor robot Cubetto, on some cognitive skills, such as the sequential ability to reconstruct stories and visual-spatial abilities, in children of 4-years-old. No differences existed between the two groups at T0. The statistical analysis showed both a significant main effect of time (pre vs post) and interaction effect (time x group) on the sequential programming abilities measured by the ad hoc Cubetto task. Thus, the experimental group performed better than the control group in programming the Cubetto path after the intervention. Nevertheless, no significant interaction effects were found related to the children understanding of pictures stories and visuo-spatial skills.

A plausible explanation of the result obtained with the Cubetto task could be linked to the learning effect of a specific task. Various cognitive competences related to that specific type of learning are probably involved but we did not find a generalization effect. Unfortunately, the research focusing on the age considered by this study (4 years-old) is still too limited to draw conclusions on the beneficial effects of coding for these younger learners, whose cognitive skills are still largely immature. Furthermore, other studies

[21] involving 5-6 years children proposed a longer intervention (8 sessions over four weeks) and found significant improvements in two executive functions: planning and response inhibition. Thus, future studies are encouraged in testing the effects of a coding intervention whose duration and articulation is greater in sustaining the interconnections between specific programming skills and children cognitive abilities.

References

[1] Wing JM. Computational Thinking. Communications of the ACM, 2006; 49(3), 33–35.
[2] Wing JM. Computational Thinking and Thinking about Computing. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 2008; 366(1881), 3717–3725. doi:10.1098/rsta.2008.0118
[3] Wing JM. Computational Thinking: What and Why? 2010. Link Magazine. Retrived from:https://www.cs.cmu.edu/link/research-notebook-computational-thinking-what-and-why
[4] Bers MU, Ponte I, Juelich K, Viera A, Schenker J. Teachers as designers: Integrating robotics into early childhood education. Information Technology in Childhood Education Annual, 2002; 14, 123–145.
[5] Bers M. Blocks to robots: Learning with technology in the early childhood classroom. New York, NY: Teacher's College Press. 2008.
[6] Bers MU. The TangibleK robotics program: Applied computational thinking for young children. Early Childhood Research & Practice, 2010; 12(2). Retrieved from http://ecrp.uiuc.edu/ v12n2/bers.html.
[7] Rogers C, Portsmore M. Bringing engineering to elementary school. Journal of STEM Education, 2004; 5(3–4), 14–28.
[8] Kazakoff ER, Sullivan A, Bers MU. The effect of a classroom-based intensive robotics and programming workshop on sequencing ability in early childhood. Early Childhood Education Journal, 2013; 41(4), 245-255.
[9] Nulli G, Di Stasio M. Coding alla scuola dell'infanzia con docente esperto della scuola della scuola primaria. Italian Journal of Educational Technology, 2017; 25(2), 59-65. doi:10.17471/2499-4324/902
[10] Sung W, Ahn J, Black JB. Introducing Computational Thinking to Young Learners: Practicing Computational Perspective Trough Embodiment in Mathematics Education, Technology, Knowledge, and Learning, 2017; 1-28. doi: 10.1007/s10758-017-9328-x
[11] Román-González, M., Pérez-González, J-C., Jiménez-Fernández, C. Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test, Computers in Human Behavior, 2017; 678-691. http://dx.doi.org/10.1016/j.chb.2016.08.047
[12] Manches A, Plowman L. Computing education in children's early years: A call for debate. British Journal of Educational Technology, 2017; 48(1), 191-201. doi:10.1111/bjet.12355
[13] Paris AH, Paris SG. Assessing narrative comprehension in young children. Reading Research Quarterly, 2003; 38(1), 36-76
[14] Bers M, Horn M. Tangible programming in early childhood: Revisiting developmental assumptions through new technologies. In. Berson IR, Berson MJ (Eds), High-tech tots: Childhood in a digital world Greenwich, CT: Information Age Publishing; 2010. 49-70.
[15] Kazakoff ER, Bers MU. Put your robot in, put your robot out: Sequencing through programming robots in early childhood. Journal of Educational Computing Research, 2014; *50*(4), 553-573.
[16] Bers MU, González-González C, Armas-Torres MªB. Coding as a playground: Promoting positive learning experiences in childhood classrooms, Computers & Education, 2019; 138, 130-145. https://doi.org/10.1016/j.compedu.2019.04.013
[17] Papert S. Mindstorms: Children, computers, and powerful ideas. New York, NY: Basic Books. 1980.
[18] Alimisis D, Kynigos C. Constructionism and robotics in education. Teacher education on robotic-enhanced constructivist pedagogical methods, 2009; 11-26.
[19] Baron-Cohen S, Leslie AM, Frith U. Mechanical, behavioural and Intentional understanding of picture stories in autistic children, British Journal of Developmental Psychology, 1986; 4, 113-125
[20] Hawes Z, Moss J, Caswell B, Seo J, Ansari D. Relations between numerical, spatial and executive function skills and mathematics achievement: A latent-variable approach, Cognitive Psychology, 2019; 109, 68-90. https://doi.org/10.1016/j.cogpsych.2018.12.002
[21] Arfé, B., Vardanega, T., Ronconi, L. The effects of coding on children's planning and inhibition skills. Computers & Education, 2020; 148; 103807.