Coding and childhood between play and learning: Research on the impact of coding in the learning of 4-year-olds

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Abstract

We propose the results of a research that combines the educational and psychological media approach, to verify the pedagogical potential of coding and robotics in the learning processes of 4-year-old children at the cognitive and socio-relational level.

The study investigated the impact of unplugged and plugged coding on the skills of spatiality, movement and problem-solving skills, storage and decoding of progressively more complex indications, and single-group interaction of 51 children and three kindergartens using storytelling and the educational robot Cubetto.

The work is based on the research carried out by Lee (2020) on the inclusion of coding in early childhood, the theoretical references of Wing (2010) about computational thinking and the theoretical frameworks proposed by Bers (2020) regarding coding as a playful dimension.

The data collected through the quantitative and qualitative tools of a pre- and post-intervention questionnaire to educators and a checklist of observations on children recorded the following:
- *an increase in children's space, motor and information-storage/decoding skills;*
- *a change in children's collaborative skills when comparing the results of the plugged and unplugged coding workshops and*
- *the impact of coding to increase children's performance skills through narrative dimension and play.*

Keywords: Coding, Kindergarten, Cubetto, Playful Dimension, Innovative Didactics.

Introduction[1]

In recent years, educational research has shown interest in computational thinking (Wing, 2006). In particular, several studies have observed a significant relationship between computational thinking and some cognitive abilities such as

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[1] This article has been developed jointly by the authors. Federica Pelizzari wrote the sections *Materials and Methods* and *Results*. Michele Marangi wrote the sections *Theoretical Framework* and *Discussion*. Pier Cesare Rivoltella wrote the section *Conclusions*. Giulia Peretti, Davide Massaro and Daniela Villani wrote the section *Introduction*. Igor Guida and Sara Di Bruno participated in the research for the STRIPES Cooperative (Milano).

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problem-solving and spatial abilities (Bers, 2020). In addition, Parten (1932) noted that, between the ages of 2 and 4 years, there is a clear shift from parallel activities to cooperative games that require an interactive component, which allows children to interact through complementary exchanges to pursue common goals. Initially, this exchange is based on specular imitation, and later, it will be based on complementary and reciprocal interactions. For this reason, coding activities and educational robotics are promoted starting from childhood.

The most recent studies on the relationship between digital media and childhood in the 3–6 years age group present two different perspectives. On the one hand, there are those who assume the need to delay as much as possible the contact between children and digital media to avoid that these compromise the balanced and harmonious development of both the physical (Rowan, 2010) and psychological and socio-relational spheres (Clement and Miles, 2018). On the other hand, others underline that the potential of using digital media with boys and girls of this age encourages greater participation and gratification in children's learning (Bach, Houdé, Léna, Tisseron, 2015), especially if grafted into articulated and coherent pedagogical practices (Couse and Chen, 2010) and as long as they are introduced in a gradual and balanced manner and their usage is constantly supervised by adult figures (Tisseron, 2013).

1. Theoretical framework

Based on this debate, the research chose to experimentally compare the impact of two different approaches to coding: the traditional one, which uses interactive digital screens among other tools, and the unplugged coding, which introduces the fundamental concepts of computer science and the logic of programming through motor and cognitive activities that do not require digital tools.

The laboratory setting activates situated and experiential learning (Rivoltella, 2013) and develops operative, cognitive, relational and reflective skills in both boys and girls. The practical experience of the laboratory combines the design dimension with concrete actions, and playful aspects with relational ones, enabling the transversal development of creativity and the ability to reflect on the creations and actions in children, both individually and collectively (Resnick, 2017). It also favours the activation of playful dynamics, which facilitate learning and the growth of personalised strategies, as many classical studies amply demonstrate (Piaget, 1951; Vygotskij, 1967; Bruner, Jolly, Sylva, 1976). In the digital era, the functionality of the game in a laboratory perspective cannot fail to take into account new experiential modes to which children are already accustomed, identifying new principles of learning (Gee, 2007) and considering the new cognitive abilities typical of generations familiar with digital games from an early age (Latham, Patston, Tippett, 2013).

Computational thinking, which is at the basis of coding, appears as an element of synthesis of these dynamics, able to conjugate mathematical logic with interpretative creativity (Papert, 1996), problem-solving with divergent thought (Resnick, 1995) and imagination with the ability to create categories from concepts (Wing, 2006).

Cubetto[2] was chosen as an educational robot, which combines references to the Montessori method (2016) for the use of objects that are easy to manipulate and use; it is designed to entice the child to play and experiment with the logic of the LOGO language (Papert, 1980), which, through the turtle, transforms the programming language not into pure abstraction, but into narrative and playful operational activity, which develops the ability to achieve goals and solve problems through observation, experimentation and repetition.

In this perspective, coding and computational thinking combine the playful dimension of learning with the collective dimension of experiential practice, following in the tracks of the more mature Media Education, which develops critical and narrative skills, social responsibility and individual reflexivity (Rivoltella, 2020).

In this logic, the research intends the practice of coding in the School of Childhood as a transversal activity, because it allows to develop computational thinking for exemplifying concepts, describing activities and procedures, and conceptualising procedures and solutions (Manches and Plowman, 2017).

Educational robotics inserted in playful situations that graft informal dynamics into formal contexts encourages social relations between boys and girls in a playware logic (Pennazio, 2015) and promotes the development of social skills according to the logic of playfulness (Lund, 2009). The research also deepened the aspects related to the relationship between computational thinking and body dynamics, spatial orientation and management and organisation of motor information, not so much in a logic of mere problem-solving, but rather on the development of non-verbal cognitive abilities (Çiftci, Bildiren, 2020).

Lee (2020) presents some passages, also included in the research presented here, which can be used to introduce kindergarten children to concrete coding experiences through specific activities such as the use of directional words or arrows and sequential words.

Computational thinking, as 'a mental attitude, a logical process that allows us to solve problems of various kinds by following specific methods and tools' (Wing, 2006) is at the base of coding.

In this perspective, the practices of coding with children favour the possibility of training computational thinking through a playful approach (Bers, 2020), which makes it easier for boys and girls to solve more or less complex problems and to articulate increasingly elaborate actions in an immersive and natural way.

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[2] Cubetto, a wooden robot with an Arduino heart designed to be used not only in elementary school, but even in the school of childhood, moves on wheels and is controlled via Bluetooth through an interface, or a perforated tablet in which is inserted 16 dowels and four different colours, each of which corresponds to a different behaviour of the robot.

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2. Materials and Methods

The research investigated the skills of spatiality and movement, storage and decoding of increasingly complex indications, development of problem-solving skills, and single interaction in a group of 51 children (28 F, 23 M) and three kindergartens. The research method used was the case study.

The research questions were as follows:

- How are space and movement reinterpreted through the lens of coding, in particular, the concepts of forwards, backwards, right and left? How do they relate to an educational robot and its operation?
- Are 4-year-olds able to make collaborative decisions using problem-solving?
- Are they able to memorise and decode indications that are more complex? How?
- How does the use of screens and digital media promote learning?

The goal of the course is to test the basic elements of coding for boys and girls of 4 years of age, with a playful and engaging style, which allows the acquisition of some skills of 'programming' in an immersive and collaborative way.

The course was developed in a modular fashion: three 1-h meetings were planned in three consecutive weeks.

First meeting:

- story with movement of the protagonist within the grid and vision of obstacles;
- explanation of the use of arrows on the grid and the indications 'start' and 'end'. Explanation of right/left with the support of coloured bracelets;
- in turn, the children physically become the protagonist of the story and have to reach some points of the grid, led by their companions or by the educator and
- the grid contains drawn obstacles to be avoided by the children.

Second meeting:

- collective game outside the boundaries of the grid, which requires the children to follow sound and visual cues (arrows) given by a tablet/projector through images and sound effects. The cues are preceded by a 'start' signal and followed by an 'end' one;
- in turn, the children guide the protagonist of the story and have to make it reach some points of the grid, marked by signs of beginning and end that change in position every time;
- before starting his/her turn, the child hands the drawn obstacle to the educator, who places it inside the grid and
- the child then guides the character on the grid from the start to the obstacle he/she designed and then to the end of the grid by looking at the images projected on the wall and hearing the sounds played.

Third meeting:

- presentation of Cubetto educational robot as the new protagonist of the story and its features and
- game involving Cubetto on the grid containing some obstacles related to the different emotions that the child could really live during the course of the route.

Each meeting saw the presence of two educators, that is, one who managed the laboratory and the other who observed the development of the experiment documented its progress on a checklist of structured observation (Castoldi, 2011) on three values: No – Partially – Yes. By No, we mean no autonomy of action and thought; by Partially, we mean partial autonomy accomplished using modelling, fading or prompting techniques by the teacher or companions; by Yes, we mean total autonomy of the child in every action and thought. The observer compiled the observation checklists, while each laboratory was running and developing observations on each individual child. The choice to use a checklist of this type is due to the wanting to observe children and then their actions in a structured way and to be able to reflect with the educators about more structured data than a simple, free observation.

This tool was created from an evaluation rubric.

The evaluation rubric was, therefore, built by developing all fields of experience with some skills' development goals. These goals led to the definition of learning objectives and indicators.

The evaluation rubric has taken into account the following six specific targets:

- developing and applying mathematical thinking to solve a number of problems;
- using new technologies with familiarity and a critical spirit;
- solving the problems encountered and proposing solutions;
- choosing between different options, making decisions;
- acting with flexibility and
- planning.

These specific targets were chosen in accordance with the framework created by Bers (2020) and Lee (2020), the MIUR National Guidelines (2012, 2018) and the Media Education Literacy Curriculum produced by Rivoltella (2020).

The creation then saw a first design of the activated dimensions of competence of computational thinking and coding and then went to decline three observable indicators that could be interesting for research purposes:

- body and movement,

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- relation to the peers and
- approach to problems.

In the 'Results' section, the descriptors referring to each indicator are given.

During the analysis of the data, in order to derive the present diagrams, the following procedure has been followed.

First, the percentages of the responses were calculated from the tables of each laboratory of each school. This was done by analysing how many 'Yes', 'Partially' or 'No' responses were given. The average for each laboratory was calculated to get an idea of the progress of single laboratories.

The next step involved the global evaluation of the evolution of responses over time, considering the data from all the laboratories. Finally, the average of the percentages was calculated to obtain a complete view of the evolution of the answers of each school, and therefore of the entire experimental sample.

3. Results

The checklists have returned interesting data about all the analysed indicators. The chart presented in Fig. 1 shows the overall trend.
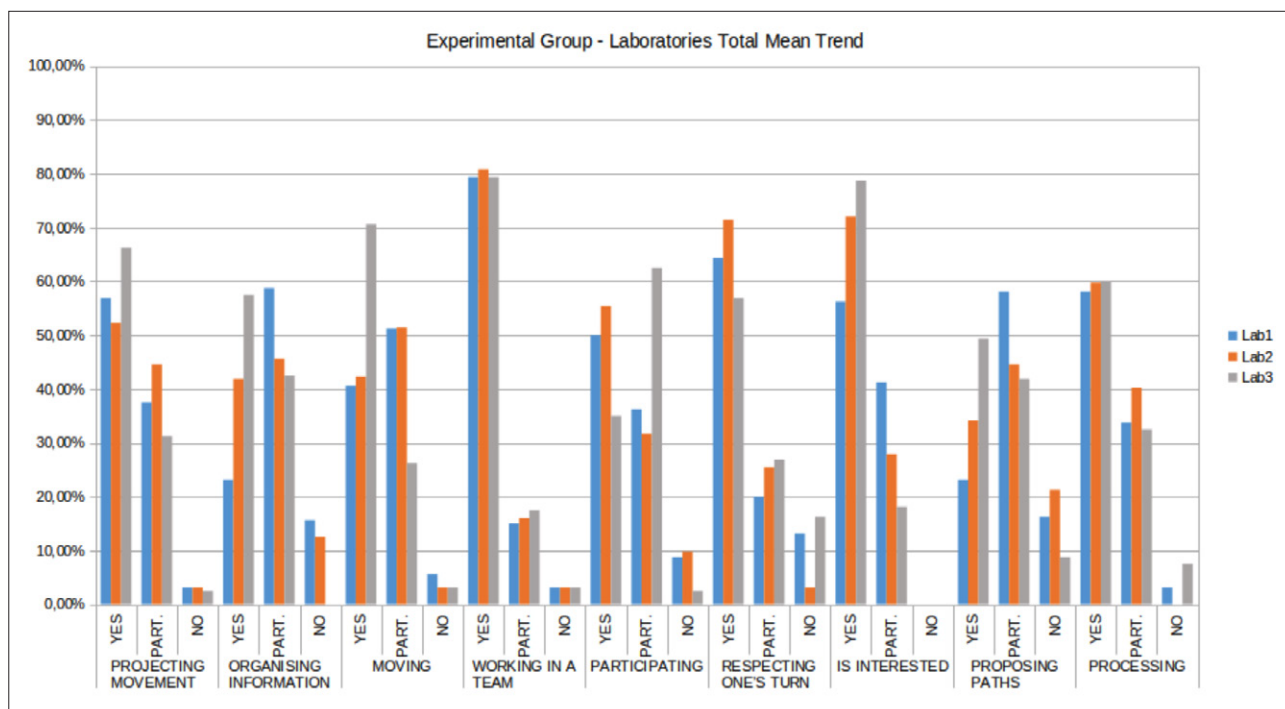

Fig. 1. Total laboratory performance

4. Indicators 'body and movement'

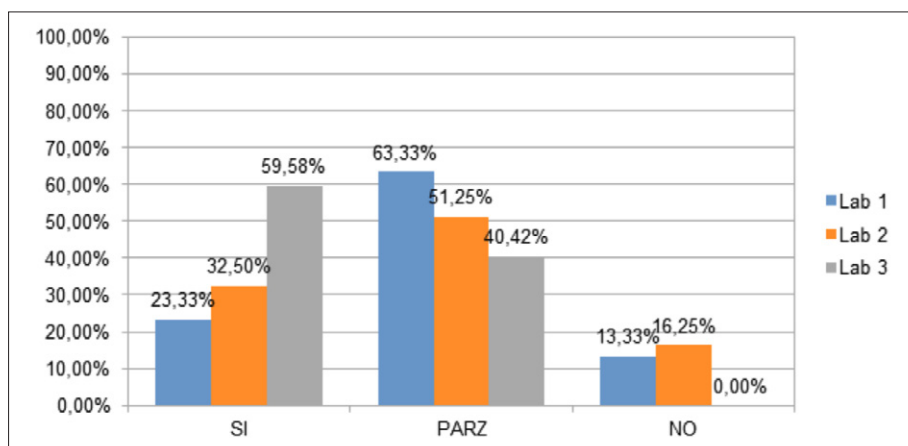1. Objective 'Design the movements of the body and object (cardboard character or cube) by giving instructions'

Fig. 2. Design the movements of the body and object performance (SI = Yes, PARZ = Partially, NO = No)

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As can be seen in Fig. 2, the growth in the target was quite large, starting from a total autonomy of 56.88% and reaching 66.25%, with 10% improvement.

The progression of the laboratories shows that the autonomy of the children in the design is slightly lower in the second laboratory than in the first (−4.6%), while it goes back up in the third (+14%), thanks to the use of Cubetto and the tablet.

2. Objective 'Organises information and puts it into practice (using arrows)'
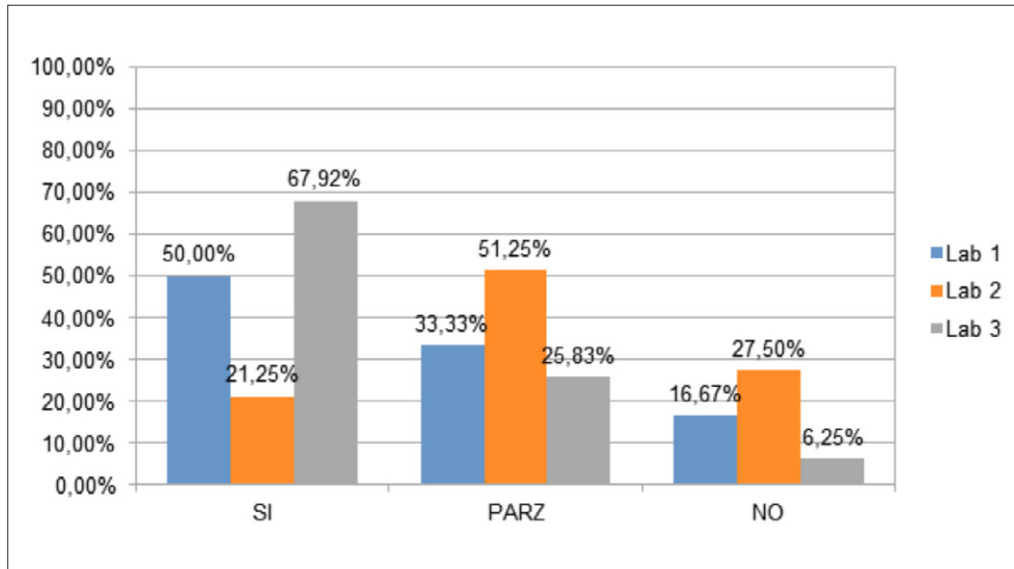

Fig. 3. Organises information and puts it into practice performance (SI = Yes, PARZ = Partially, NO = No)

The children only had partial autonomy accomplishing this goal in the first two laboratories, but managed to improve as the laboratories progressed, improving by 18.75% between the first and second and by a further 15.62% between the second and third.

The objective related to the organisation of information and its implementation presents ambivalent outcomes (Fig. 3), which make it particularly significant within the indicators 'body and movement'.

The outcome of the third laboratory is the lowest of the three compared to full autonomy: 57.5%, compared to 66.2% of objective 1 and 70.6% of objective 3. However, as a relative growth between laboratory 1 and laboratory 3, here the highest implementation is recorded: +34.4%, compared to +30% of objective 3 and +9.4% of objective 1.

This is the only of the three objectives of this area that, at the end of the path, does not record 'No'. 'No' recorded the best performance relative to the decrease of the negative value in the development of the route: −15.6%, compared to −2.5% of objective 3 and −0 and 6% of objective 1.

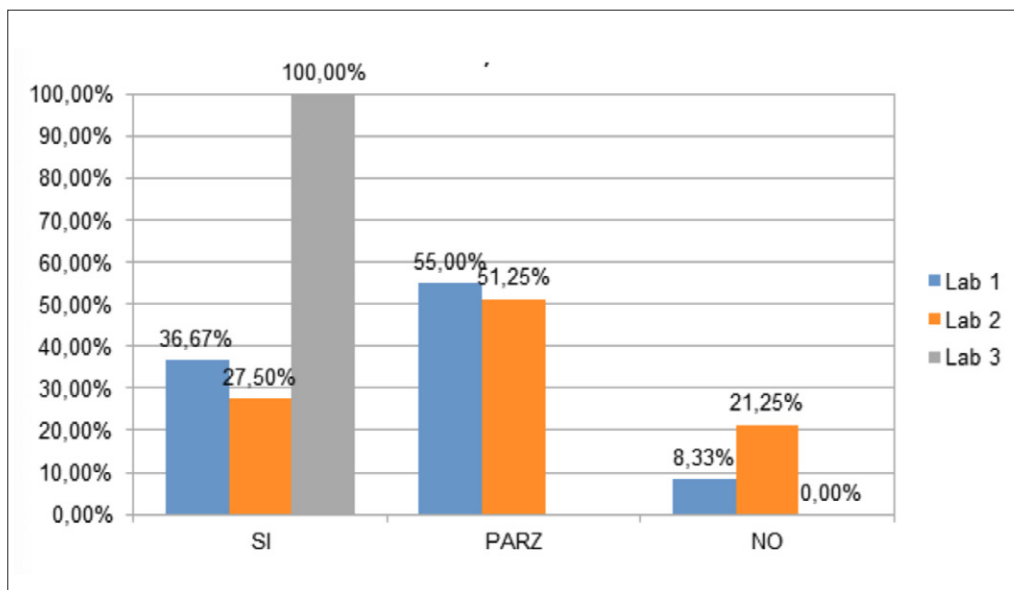3. Objective 'Moves himself, his partner, the object (cardboard character or cube) respecting obstacles'

Fig. 4. Moves himself, his partner, the object respecting obstacles' performance (SI = Yes, PARZ = Partially, NO = No)

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The Fig. 4 shows a clear improvement between the first and third laboratory in the above-mentioned objective. In fact, the growth of total autonomy of action and thought in the children is equal to 30%.

There is a significant difference between the net improvement that took place between the third laboratory with the second (+28.3%) and the slight improvement that occurred between the second and the first laboratories (+1.7%).

5. Indicators 'Relations with peers'

4. Objective 'Working in pairs/in groups respecting partners'
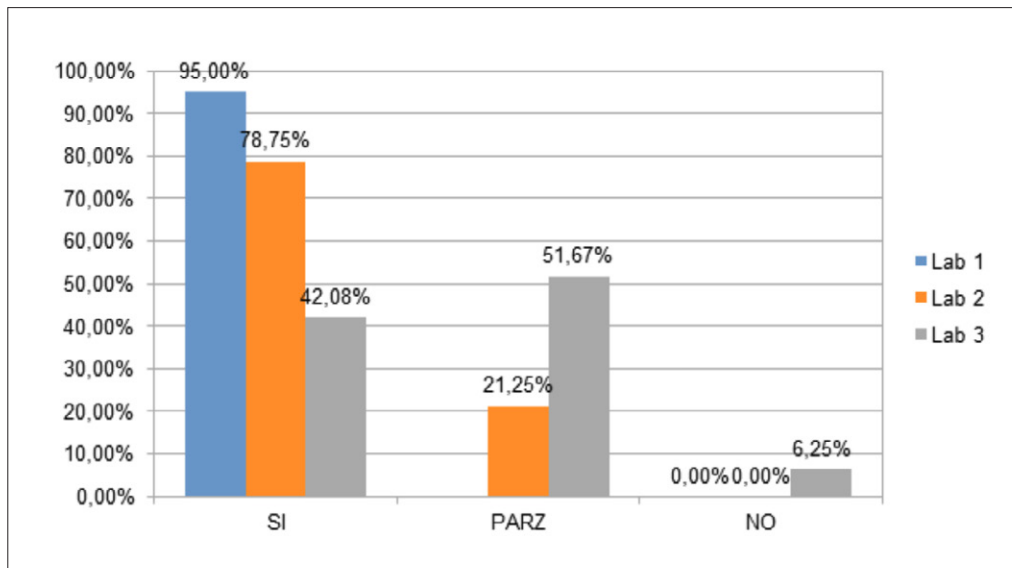

Fig. 5. Working in pairs/in groups respecting partners' performance (SI = Yes, PARZ = Partially, NO = No)

In all three laboratories, all couple and group activities show a constant percentage of competence.

The oscillation of autonomy with respect to this objective is minimal and symmetrical (Fig. 5): the second laboratory has an increase (+1.4%) when compared to the first, while the third registers the same value as a decrease (−1.4%). The percentage of the total absence of autonomy remains stable in all three laboratories, with a value of 3.1%.

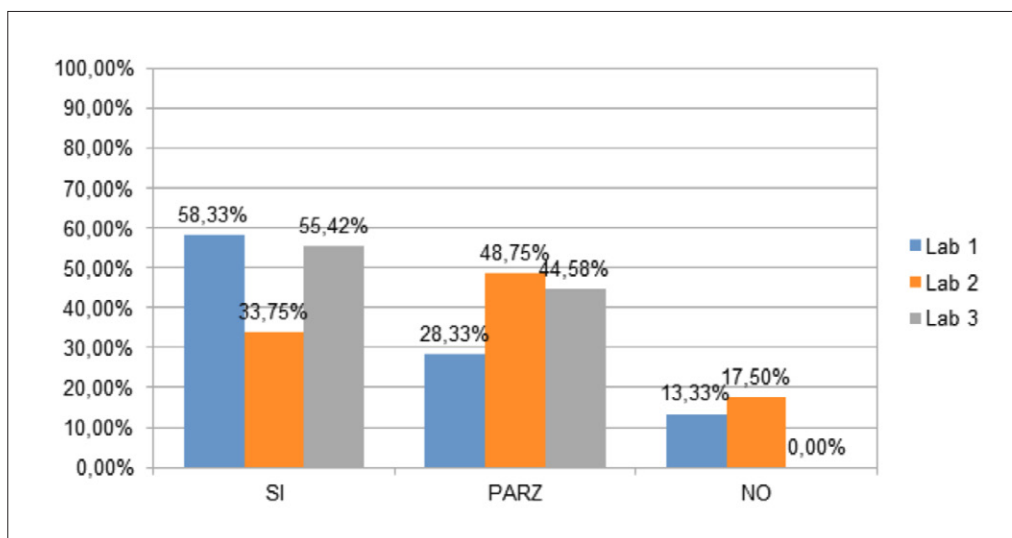5. Objective 'Participates in a proactive and attentive way to the proposed activity'

Fig. 6. Participates in a proactive and attentive way to the proposed activity performance (SI = Yes, PARZ = Partially, NO = No)

The Fig. 6 shows how while there is an improvement of 5.4% between the first and second laboratories, in the third laboratory there is a clear deterioration of the total autonomy of children of 20.4%, but an increase of partial competence: +26.3% over the entire route and +30.8% between the second and third laboratories.

The total absence of autonomy decreases over the entire path (−6.3%), after witnessing a slight increase between the first and the second laboratories (+1%).

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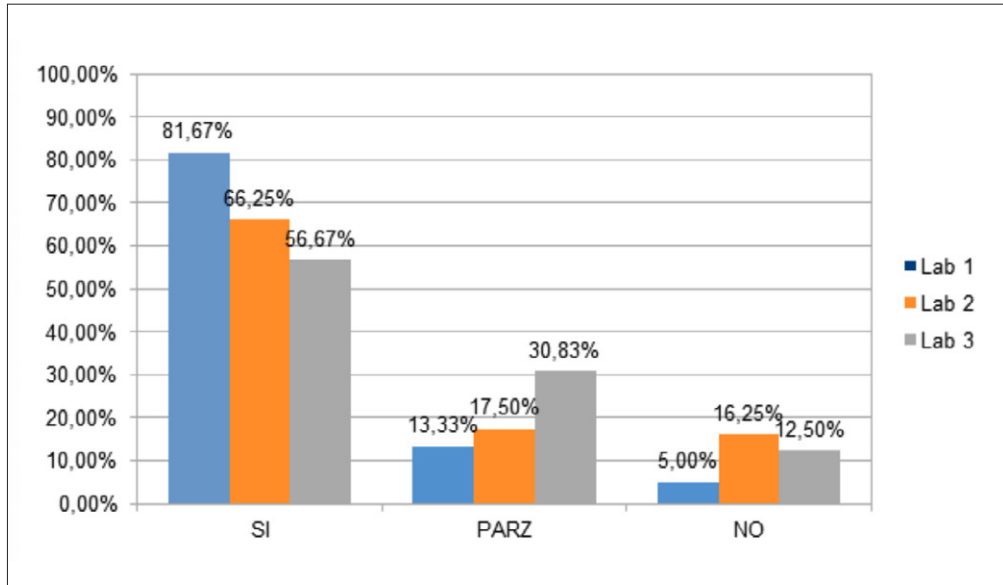
6. Objective 'Respect your turn'

Fig. 7. Respect your turn performance (SI = Yes, PARZ = Partially, NO = No)

Between the first and the second laboratories, the autonomy of the best children is 7.08%, while there is a deterioration of 14.58% between the second and third laboratories, which is 7.5% when comparing the third laboratory with the first. The value of NO (total absence of autonomy) records a decrease between the first and second (−10%) laboratories, while it grows between the second and third (+ 13%) laboratories (Fig. 7). This objective is the only one in the area that shows an increase in the total lack of autonomy.

6. Indicators 'Approach to problems'

7. Objective 'Interested in the storyboard and the main object (the body, cardboard character or cube)'
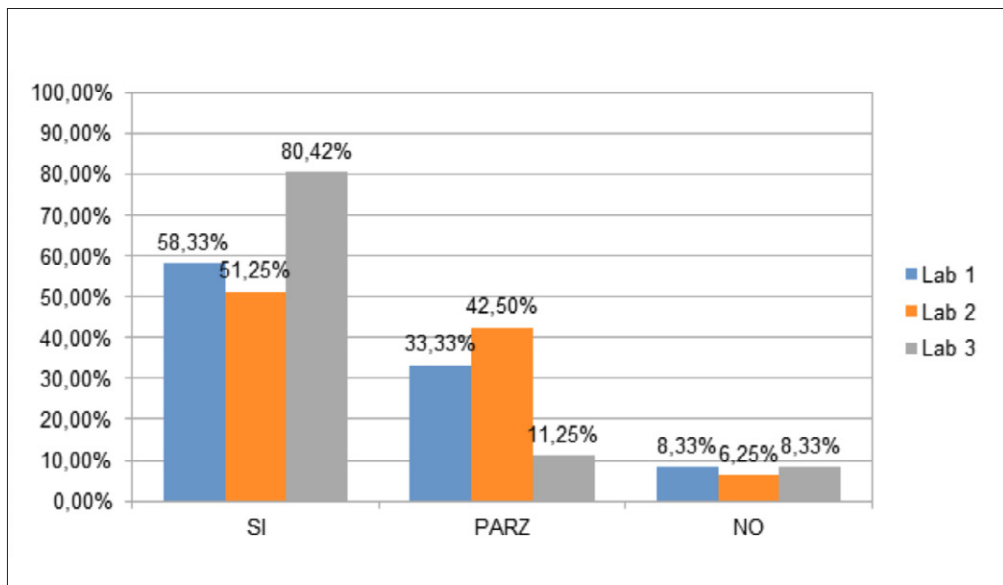

Fig. 8. Interested in the storyboard and the main object performance (SI = Yes, PARZ = Partially, NO = No)

The improvement of the objective is constant, with a relative increase of 22.5% between the first laboratory and third laboratories and +6.7% between the second and third laboratories (Fig. 8).

This objective is the only one in which the range of total absence of autonomy never occurs in absolute terms, either at the start or during the course of the journey.

8. Objective 'Proposes functional paths to the movement of the body and object (cardboard character or cube) overcoming obstacles'

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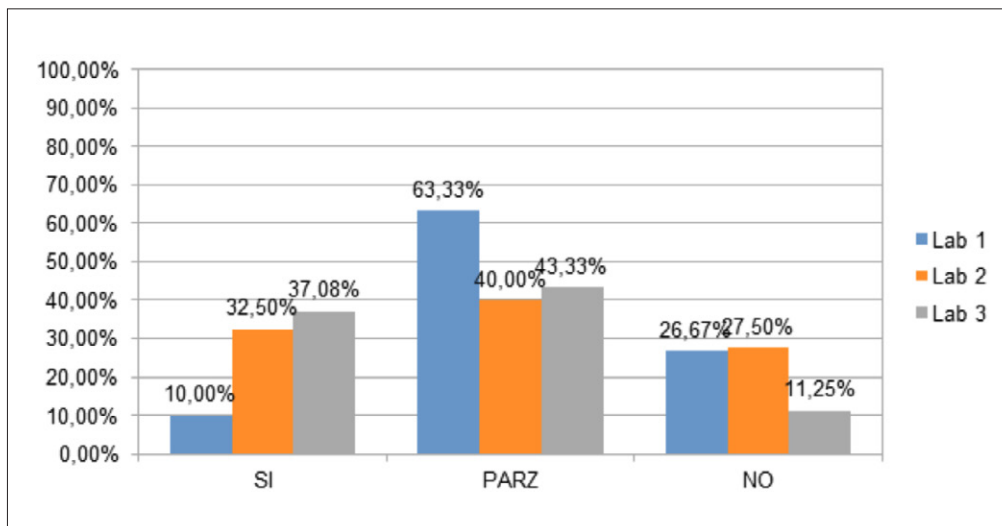
Fig. 9. Proposes functional paths to the movement of the body and object overcoming obstacles' performance (SI = Yes, PARZ = Partially, NO = No)

This has been the most challenging goal for the children, especially at the start. In fact, both in the first and second laboratories, the majority of children have never been able to be significantly autonomous in proposing functional paths, while they succeed in the third laboratory. The overall improvement percentage increases between each laboratory: by 11% between the first and second and by 15.2% between the second and third. In absolute terms, total autonomy grows by 26.3% between the first and third laboratories (Fig. 9).

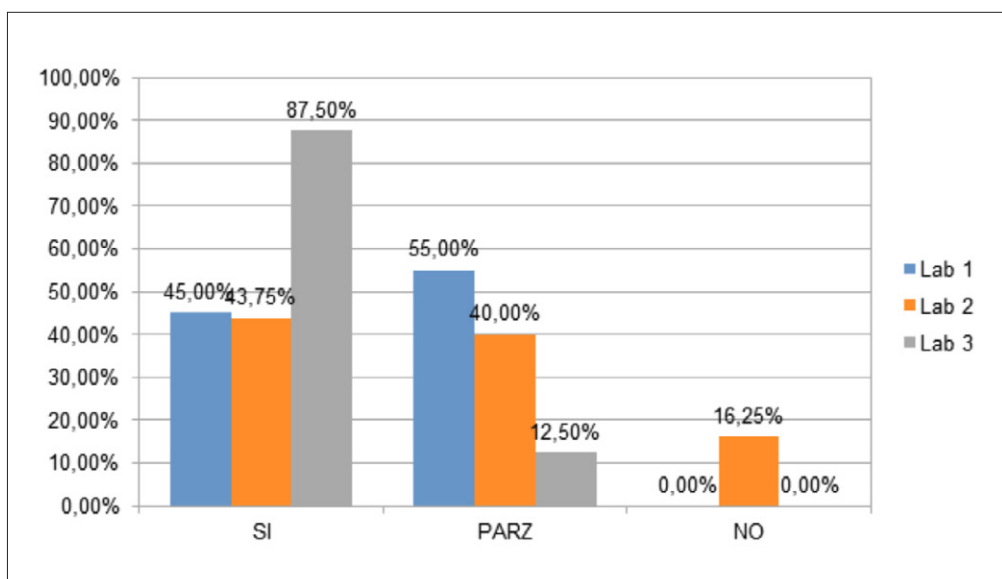## 9. Objective 'To elaborate the phases of the carried out distance'

Fig 10. To elaborate the phases of the carried out distance performance (SI = Yes, PARZ = Partially, NO = No)

The objective is stable, noting how, however, the non-autonomy increases during the third laboratory: a +7.5% is recorded compared to the second and a +4.4% if compared to the first (Fig. 10).

A zero value of total lack of competence is recorded between the first and second laboratories (−3.1%), but it is followed by an increase between the second and third laboratories (+7.5%). In absolute terms, between the beginning and the end of the journey, the total lack of autonomy with respect to this objective grew by 4.4%.

7. Discussion

The data from the research, analysed in the previous paragraph, allow us to synthesise the initial framework of the research with new perspectives of development. In particular, in relation to the starting themes, three relevant aspects emerge from the research.

Firstly, the use of screens and digital devices appears strategic to stimulate motor and recreational activities even in children of age 4 years (Fjørtoft, 2004), but only if it is a passive and hypostatic use. In this perspective, it is clear that

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coding is an educational medium activity, able to mediate between physical and digital reality and to stimulate creativity to develop motor and logical skills (Couse and Chen, 2010; Tisseron, 2013).

Secondly, the tendency of digital media and technological objects to develop attitudes based more on personal and individual attraction and less on the ability to collaborate is confirmed (Clement and Miles, 2018). In this sense, the ability to create designs that can be inspired by the framework of community technologies (Rivoltella, 2017) seems central.

Thirdly, the research shows the importance of combining technological knowledge and narrative involvement, highlighting the impact and potential of frames and narrative tools as strategic supplements to facilitate in 4-year-olds both the ability to visualise and concretise abstract aspects as a semiotic domain (Gee, 2007) and the ability to identify problems and to know how to solve them in a narrative and playful way.

The first area investigated is the development of motor skills and the activation of complex movements. The most interesting figure is the one related to the second objective, 'organises the information and puts it into practice through the arrows', which, while being the lowest of the three as the final value, records the highest increment of success between the first and third laboratories, with an increase of 34.4%. The use of media and technology seems to facilitate the capacities of children not only in the management of useful information, but also in their transformation into operational practice (Resnick, 2017), thus promoting the conceptualisation skills of increasingly complex information and their activation in more performative movements if referred to programmable objects which are concrete and external to one's body.

The fact that even the third objective 'moves itself, the companion, the object (cardboard character or Cubetto) respecting the obstacles' registers a 30% increase of success between the first and last laboratories seems to be complementary to this outcome, confirming the impact of mediality and programming of external objects on the development of movement skills and motor information management.

In the second area investigated, which focuses on the relationships between peers and collaborative skills developed by boys and girls, the first indicator 'the ability to work in pairs or in groups, respecting the companions' does not record significant variations in the progression of the three laboratories.

It is interesting to link the conflicting data of the other two objectives. In the case of 'participates in a proactive and attentive way to the proposed activity', the decrease of 15% for the fully affirmative value is mitigated by the increase of +26.3% over the entire journey and +30.8% between the second and third laboratories. In this case, there seems to be a less-participatory behaviour, especially in the intermediate value recorded by the use of screens and media instructions, which is partially reactivated by the use of the robot Cubetto. However, this data acquires further meaning when compared with the results of the last goal 'respects your turn', which records a decrease of 7.5% overall and is the only objective of the area that shows an increase in the total lack of autonomy in the development of the route. The combination of data on the increase in distraction and the lack of respect for one's turn does not seem to attest to a lack of interest on the part of children, but rather the power of the medial devices of the robot to 'abducte' attention on a more individual than a collective level and stimulate the desire for immediate use, at the expense of the ability to be part of the group.

This very high personal involvement is confirmed by the data related to the outcomes of the first objective, 'is interested in the storyboard and the protagonist object (the body, cardboard character or Cubetto)', which recorded an increase of 22.5%. The power of narrative mediation and the progressive possibility of seeing and physically manipulating a character that also offers immediate feedback on the outcomes of the planned path seem to involve a lot of boys and girls. The objective 'proposes functional paths to the movement of the body and object (cardboard character or Cubetto) overcoming obstacles' confirms the progressive development of the skills of the children, whose total autonomy grows by 26.3% between the first and third labs.

The progressive use of media and robots seems to facilitate the synchrony between programming skills and the development of increasingly complex practices, which appear to be even more facilitated with the use of an autonomous object located in the narrative space, as opposed to having to think of your body as a character. The use of the robot and the narrative background catalyse the operative attention (Wing, 2010) and the immersive posture of the children, but they do not facilitate or worsen their reflexive posture.

Conclusions

The data proposed and analysed in this article highlights some particularly significant aspects in relation to the impact of coding and the educational use of robots in an early cluster such as boys and girls of 4 years, a sample that has so far seen very little studies, which adopted this particular educational media perspective.

First, the significant impact of a mediator object, such as the robot, in the growth of the ability of children to select and process useful information and translating them into actions and appropriate movements consistent with the mandate to achieve the objectives set becomes evident. We consider it strategic to develop the relevance of coding in order to achieve a significant boost of children's abilities to comprehend and elaborate information, select the most functional ones and translate them into physical actions coherent with the objectives that are set.

Secondly, for 4-year-olds, screen mediation tends to disperse their social attention and their ability to manage relationships with peers. This relational difficulty should not be simplified as a loss of attention or a lesser motivation, but as a shift from a more social attentive posture to a more self-centred one. In perspective, it would be interesting to further

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develop strategies that allow children to learn as soon as possible not to self-centre and to develop relational skills with and in the media and to develop functional skills for a more conscious and mature use of it, even in later ages.

Lastly, the research confirms the implementation of performative ability and procedural ease by children in contexts where narrative backgrounds are no longer perceived in an abstract way, but in a deeply immersive one, with the possibility of physically moving and manipulating concrete objects, which translate actions and strategies and allow to immediately verify the feedback and possible further developments, like in video games.

All three aspects summarised here seem to us to be significant in hypothesising and strengthening a further research perspective, to investigate to what extent the use of coding and computational thinking with boys and girls from kindergarten should not be limited to a technological perspective and functionalist logic of pure problem-solving. From the data analysed, here emerges the centrality of the average educational dimension, which, through the intertwining between informal playful dimension and formal logical activities, allows children to develop analytical awareness and procedural creativity. The Media Education approach appears strategic to identify and problematise the new pedagogical needs to be developed in reference to the new generations of childhood, to understand how to rethink and articulate the relationship between the physical and biological needs of children and the characteristics and stimuli typical of a society and a culture increasingly immersed in digital media.

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