ENHANCING LANGUAGE AND SOCIO-EMOTIONAL SKILLS IN PRE-SCHOOL CHILDREN: A MULTISENSORY ITINERARY WITH THE THYMIO ROBOT

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Abstract

Educational robotics is commonly acknowledged for fostering computational thinking. Nevertheless, there are several examples where it also excels in enhancing motivation, collaboration, and the development of life skills, even though these applications are not yet widely adopted. This research aims to investigate the impact of an educational robot-based program on the cognitive and cross-functional abilities, such as language improvement and socio-emotional skills, of preschool children aged 4 to 6. Our approach revolves around a playful curriculum grounded in multisensory teaching methods, group activities, and the use of the Thymio robot, which plays a central role in specially crafted laboratory materials. For experimentation, a between-subject design was employed, utilizing assessment tools from the Erickson catalog. The sample involved 72 children from two nursery schools in Turin and utilized mixed-effects models for data analysis. The results highlight the efficacy of this approach, indicating improvements in posttest for both the development of language and socio-emotional skills in the experimental group. In conclusion, the pedagogical itinerary underscores the potential of educational robotics in fostering students' skills, even at the early stages of their educational journey.

Keywords: Educational robotics, language skills, socio-emotional skills, multisensory itinerary, nursery school.

1 INTRODUCTION

In today's world, educational robotics is widely recognized and has primarily been assessed for its contribution to the development of computational thinking, with a significant emphasis on STEAM (Science, Technology, Engineering, Art, Mathematics) skills [1-4]. By using robots as interactive tools, students learn to think logically to solve complex problems, and understand the fundamentals of algorithms. These skills not only apply to robotics but also have broad applications in real-world scenarios, preparing individuals to tackle the diverse daily challenges. Beyond these core aspects, educational robotics offers a myriad of additional benefits. It has a remarkable ability to motivate students, making the learning process more engaging and enjoyable [5-9]. This heightened motivation often translates into improved learning outcomes. Successful international examples confirm its benefits for motivation, collaboration, and inclusivity, which facilitate the acquisition of new skills and attitudes necessary for making responsible choices and acting responsibly in everyday life [7-9]. While these various experiences provide valuable insights, researchers stress the need for further exploration in this area. These encompass assessing the long-term influence of robotics on learning outcomes and the widespread integration of robotics into diverse educational stages. In fact, as asserted by Arocena et al. [5], it's worth noting that robotics predominantly serves as a tool for individual skill development, while its potential to promote teamwork has yet to gain widespread traction. Moreover, in general, these activities are carried out outside the school environment, often in extracurricular settings [6]. Finally, only a limited number of initiatives have been specifically designed for preschool education [2,5]. To help bridge this gap, our study seeks to explore the effects of an educational robot-based school program on the cognitive and transversal skills of preschool children. Specifically, the educational robot, named Thymio [10], was employed as a learning mediator to promote language and socio-emotional skills among students aged from 4 to 6 years old in nursery schools. This work presents a playful itinerary based on multisensory teaching, group activities, and the use of the Thymio, which played a central role in different materials created ad hoc for the laboratory (e.g., it becomes a character of different narratives). These materials constitute the educational kit designed and produced to support the itinerary: it includes two picture books, nursery rhymes, puzzles, play mats, podcasts, and cartoons. A

series of lessons were planned for the itinerary, each with specific organizational, didactic, and teaching objectives. The lessons progressively increase in difficulty, initially focusing on language dimensions and later incorporating scientific and emotional aspects, including social aspects. All tools are designed to accommodate learners with diverse backgrounds, learning styles, and abilities. This ensures that all students can participate effectively and benefit from hands-on robotics education.

The research methodology is based on a between-subject design, where Control Group (CG) and Experimental Group (EG) were tested using two assessment tools from Erickson catalog: the "SR 4-5 School Readiness" [11] test and the "I know my emotions" questionnaire [12]. At the end of the learning path, after approximately 3 months, both groups were re-tested using the same assessment tools. The study was replicated three times, involving a total of 72 children aged 4 to 6 years old, from two nursery schools in Turin. Studies yielded positive results, indeed experimental groups performed better in posttest both for language and socio-emotional skills. This work emphasizes the effectiveness of the itinerary and demonstrates the potential of educational robotics in developing students' skills, even at the early stages of schooling.

2 METHODOLOGY

We adopted a quasi-experimental research approach using a between-subject design, following the guidelines outlined by McBurney & White [13]. This design involved the formation of both control and experimental groups, which were assessed both before and after the intervention through pretest and posttest evaluations. During the study, the CG engaged in the regular teaching activities offered at the school, while the EG additionally followed the structured pedagogical itinerary with the Thymio robot as a mediator.

2.1 Context and participants

The sample was not randomly chosen; participants were instead selected from two schools (school A, school B) located in the city of Turin (Italy), which agreed to participate in the research study.

These schools have distinct social, economical, and cultural backgrounds. School A is a public school located in a suburban neighborhood within the city. Its curriculum is designed to provide the highest level of inclusive education, with a specific focus on fostering respect and communication among educational stakeholders. In their planning, teachers constantly take into account the diverse needs and life goals for their students. On the other hand, School B holds the status of private school and is located in the city center. Here, pupils are well behaved and polite, demonstrating positive attitudes towards their learning. School leaders have implemented systems to monitor the student development, with the primary goal of ensuring successful learning outcomes for all.

A simple random probability sampling method was employed to form both groups within each school. A total of 72 students, ranging from 4 to 6 years old and enrolled in the final year of nursery school, participated in the study. The EG comprised 38 pupils (School A: 15; School B: 23), while the CG consisted of 34 (School A: 15; School B: 19).

2.2 Instruments and Tools

Various variables and tools were carefully considered to effectively address the research goals of the study. Specifically, we identified three pivotal index variables:

- *Language skills*: the range of cognitive abilities required for proficient comprehension and expression in both written and spoken language.
- *Emotional skills*: the individual's abilities to effectively recognize and reflect upon their own emotions as well as the emotions of others.
- *Social skills*: the set of abilities that facilitate positive social interactions and pro-social behaviors within interpersonal relationships.

Considering that our study participants were in the final year of nursery school, these abilities played a significant role within the framework of *"School Readiness"*. Indeed, this term denotes the fundamental competencies essential for a seamless transition to primary school and frequently serves as an indicator of prospective scholastic achievement.

2.2.1 Assessment tools

To assess the aforementioned abilities, we employed two standardized evaluation tools sourced from the Erickson catalog. Specifically, these tests were administered both before and after the intervention (as pretest and posttest).

For the assessment of language skills, we used the *'Language Skill'* battery from the 'SR 4-5 School Readiness' catalog [11] (Fig. 1, left side). This test comprises five sections with a total of 50 items. The scoring varies between the items, and ranges from 0 to 1 or 2 points. The minimum possible total score is 0, while the maximum attainable score is 56.

The evaluation of social and emotional skills was conducted using the *'I Know My Emotions'* questionnaire [12], also sourced from Erickson catalog (Fig. 1, center). This test consists of 20 items, organized into five subcategories, each addressing four primary emotions (i.e., joy, anger, fear, and sadness). The questions are designed with increasing levels of difficulty, and all of them require participants to observe an illustration before responding. A score of 1 or 0 is assigned to each item based on the accuracy of the response (1 point for a correct answer, 0 points for a wrong answer). Consequently, the minimum possible total score for this test is 0, and the maximum achievable score is 20.

2.2.2 The Thymio robot

Thymio [10] (Fig. 1, right side) is a versatile, small robot with a neutral appearance suitable for students of all ages. In this study, we utilized its six pre-programmed behaviors, each associated with a color: Green (friendly), Yellow (explorer), Red (fearful), Purple (obedient), Light blue (investigator), Blue (attentive). Truly, the Thymio robot played a central role in the itinerary, participating in stories (as imaginary characters), games, and hands-on activities. Using Thymio in preschool education offers numerous advantages, as it aims to familiarize students with digital technologies right out of the box. Thus, we incorporated its pre-programmed behaviors into our activities, with a focus on each behavior's associated color and specific movements. By using the five capacitive buttons on the top of the robot (four arrows and a central button), users can select a preinstalled behavior to command Thymio in the environment.

Due to its ability to exhibit different behaviors depending on the color set, the Thymio robot was fully exploited during the educational proposal. Leveraging storytelling concepts, this educational tool played a key role in the sessions, contributing to the construction of a well-structured itinerary with a strong emphasis on a multisensory approach.

Figure 1. Instruments and tools used in the experimentation.

2.3 Pedagogical Design

Our itinerary is grounded in the national and international curriculum framework [14-16], drawing on its visions, key competencies, and achievement principles. Indeed, it is specifically designed to promote School Readiness through a series of well-structured sessions.

Learning by doing is the preferred learning strategy during all sessions. It promotes active learning by implementing various pedagogical methods, including Cooperative Learning, Role Play, Circle Time, Peer Education, and Problem Solving. By incorporating these methods in our sessions, the proposal can act as an important step towards the inclusion of all students.

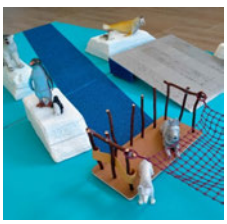
Moreover, ensuring constant support with dedicated resources is a key element to keep the learners' focus on the activities. To this end, the itinerary emphasizes the transformation of abstract concepts into tangible, real-world experiences. Traditional materials, custom-designed for the learning path, are combined with the technological tool. Consequently, the Thymio robot assumes the role of a pedagogical mediator in the learning process, supporting students in acquiring new knowledge.

2.3.1 Materials

The itinerary offers a wide array of carefully curated materials. These materials were meticulously designed to stimulate collaboration and foster the co-construction of knowledge. They have been thoughtfully tailored to the research goals and capabilities of pupils within the age range of 4 to 6 years. In conjunction with the use of the Thymio robot, the materials not only serve as educational tools but also as catalysts for interactive learning experiences, encouraging young learners to actively engage with one another and collaboratively build their understanding of various concepts, including robotics and computational thinking.

Table 1 summarizes the educational materials that were designed for the study.

Table 1. List of educational materials

Material	***Type***	***Description***	***Goal***
 Title: "Semplicemente Thymio"	***Books (Picture book)***	Introduction of Thymio robot and its behaviors, portrayed as characters.	Help students understand the purpose of the pedagogical itinerary and motivate them to learn.
	***Books (Nursery-rhymes)***	Explanation of Thymio's pre-programmed behaviors. Six brief poems to describe specific characteristics of the robot: the ways it can move following specific behavior.	Different morphosyntactic, lexical and textual features attract students, leading them to memorize the correct command and develop unconscious reflection about the language.
 Title: "Emozioni in viaggio con Thymio"	***Books (Picture book)***	A sequel to the first picture book, it is a journey through the universe, each story set in a specific world, by developing one primary emotion.	Allow the comprehension of Thymio's commands, with the awareness of the emotion vehiculated by the tale.
	***Tools (Puzzles)***	They depict some key moments of the picture book, titled "Semplicemente Thymio".	Encourage pupils to build a temporal reorganization of the story through cooperative learning.
	***Tools (Planets play mats)***	Designed to simulate Thymio's actions above planets with the same physical and narrative characteristics as those in the "Emozioni in viaggio con Thymio" picture book.	Provide pupils with opportunities to practice performing increasingly abstract sequences of actions.

	***Tools (Command strip)***	A plywood strip that was created to enter and order the commands that identify how Thymio moves based on the stories.	Enhance computational thinking and code-literacy abilities (i.e., anticipation, completion, debugging, and sequencing).
	***Multimedia (Podcast)***	Digitally recording of the reading of the picture book to allow for autonomous replication while preserving the same emotional impact as the original reading by the author.	Allow the analysis of the story's lexical and morphosyntactic features, or access to voice nuances to discover specific emotions.
	***Multimedia (Cartoon)***	A stop-motion cartoon based on the picture book “Emozioni con Thymio” and about happiness.	It is a way to furnish a wide range of mediators and provide a link for the next hands-on activities in the classroom.

2.3.2 Didactic itinerary

The itinerary was designed to progressively challenge pupils during the lessons. It starts with simple sessions of about two hours duration each and progresses to activities that require higher levels of skills, following an incremental approach. These sessions incorporate cognitive training through the use of specific materials: starting with simple instructions, they gradually require children to make increasing cognitive efforts in the area of memory, communication, application, and problem solving.

In line with the research objectives, the itinerary is divided into two sections, each with different goals, strategies, and activities: the language section and the socio-emotional section. All of these are preceded by an introductory lesson on robotics. The following is a detailed presentation of the pedagogical itinerary.

In order to promote a guided discussion about the constant presence of robots in daily life, and thus to identify similarities and differences between robots and humans, a brainstorming session was conducted following an introduction to the world of robotics. Additionally, a series of cooperative and competitive games were used to introduce the Thymio’s features and start stimulating group collaboration.

The *language section* was divided into four sessions, seen as a sequential flow in which each meeting builds upon the previous one. The reading of the picture book “Semplicemente Thymio” introduces the semantic and lexical aspects of the story, which are further explored through verbal and hands-on reconstruction using puzzles (for a description of the materials, see *Table 1*). During these activities, cooperative learning supports children in creating puzzles. They can talk and help each other by listening and welcoming peer’s ideas, encouraging them to communicate and collaborate. Thus, the core of the language section’s activities starts, represented by the nursery rhymes of the Thymio robot. This stage does not focus solely on repeating the nursery rhymes but on increasing awareness of the social values associated with the language. It transitions from focusing on the sound of words to vocabulary definitions and explanations of Thymio’s commands. The linguistic section ends with the cartoon, which shows a practical demonstration of the sequence of actions necessary to interact correctly with Thymio. Specifically, the cartoon represents the link between the two sessions, giving pupils another educational medium that leads to a collective discussion about the linguistic and emotional aspects of the story.

The *social and emotional section* follows a circular path, in which every meeting is conducted with the same pattern. It is based on the picture book “Emozioni in viaggio con Thymio”, where each story immerses children in a different world each time. This allows them to explore every primary emotion while experimenting with Thymio's commands. Indeed, they must follow the guidelines provided by the stories they have heard to identify the hidden commands and then arrange the sequence of instructions on the command strip. Through the resulting algorithm, children take turns coding each command and moving Thymio over the model, following the story-derived algorithm.

Figure 2: Highlights of didactic activities that involve playing with robots, reading books, and making puzzles

3 RESULTS

We analyzed the collected data using Mixed-Effects Models [17], through the lme4 package in R [18]. Specifically, two different analyses were conducted: the first focused on language skills, while the second addressed socio-emotional skills. Both analyses included fixed effects and random effects, as follows:

- Subject was considered as a random effect;
- Time (with *Time 1* as the pretest and *Time 2* as the posttest); Group (differentiating between the CG and EG), School (with distinctions between public and private schools) were considered as fixed effects.

As previously mentioned, our sample comprised N = 72 participants, equally divided between the two groups, with each group assessed in both pretest and posttest sessions. This resulted in a total of n = 144 observations.

Table 2. Linear mixed effects model results for language data analysis

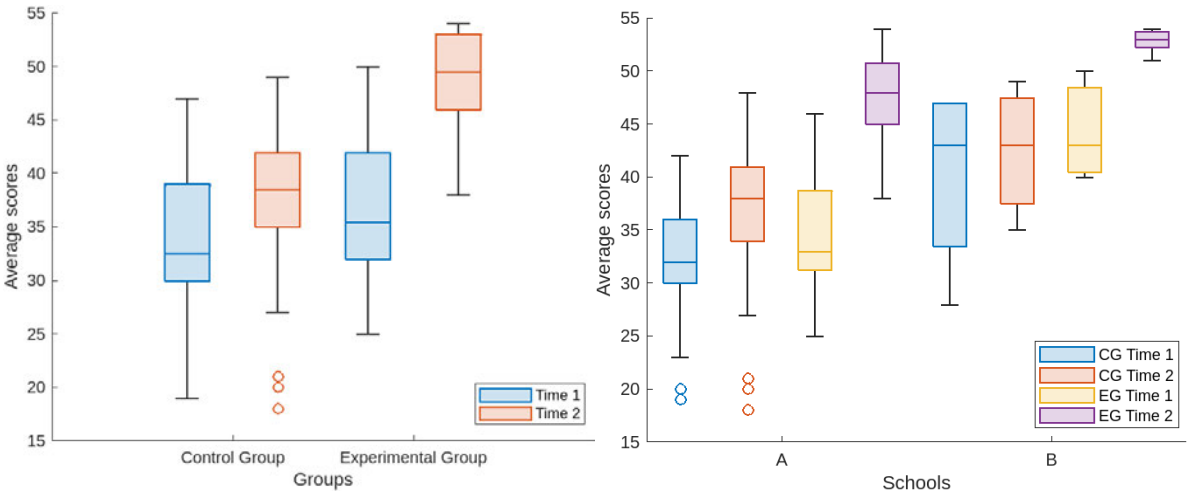
Random Effects	***σ^2***	***Std. Dev. (SD)***
Subject (Intercept)	31.53	5.615
Residual	9.95	3.154

Fixed Effects	***Estimate***	***Std. Error (SE)***	***df***	***t-value***	***p-value***	
(Intercept)	32.5289	1.3685	80.6201	23.769	2e-16	***
Time 2	4.3235	0.7651	70.0000	5.651	3.19e-07	***
EG Group	3.3279	1.5219	87.4473	2.187	0.0314	*
School B	1.1062	1.4459	69.0000	0.765	0.4468	
Time 2 : EG Group	7.7817	1.0531	70.0000	7.389	2.42e-10	***

*Number of obs. = 144, Number of subj.= 72, *p < .05, **p <.01, ***p <.001*

Addressing the first objective of this research, Table 2 presents the assessment results for language skills. The p-values indicate statistical significance for the fixed effects ($2*10^{-16}$; $3.19*10^{-7}$; 0.0314; $2.42*10^{-10}$), with the exception of the "School" variable.

At Time 2, we observed a development in language skills in both the CG and EG (see Fig. 3(a)). However, there were notable differences in the average scores. In fact, the CG saw an increase from 33.15 in the pretest to 37.47 in the posttest, while the EG achieved an average score of 48.63 after the treatment, starting from 36.53 at Time 1.



a) *b)*

Figure 3: Comparison of median scores in control and experimental groups (CG, EG) for the language abilities test: (a) pretest (Time 1) and posttest (Time 2), and (b) grouped by schools (A, B).

These results align with our expectations. Precisely, given the young age of the participants, which encourages rapid skills development, we anticipated an overall improvement in language skills within the entire sample. Notably, the results also reveal a significant difference between the groups after the treatment. In particular, the EG obtained a more substantial improvement in language skills compared to the CG. It indicates that the proposed itinerary had a positive effect on the language proficiency of the participants. The results are also confirmed by the differences in median scores between pretest and posttest, when groups are divided by school affiliation (Fig. 3(b)).

Table 3. Linear mixed effects model results for socio-emotional data analysis

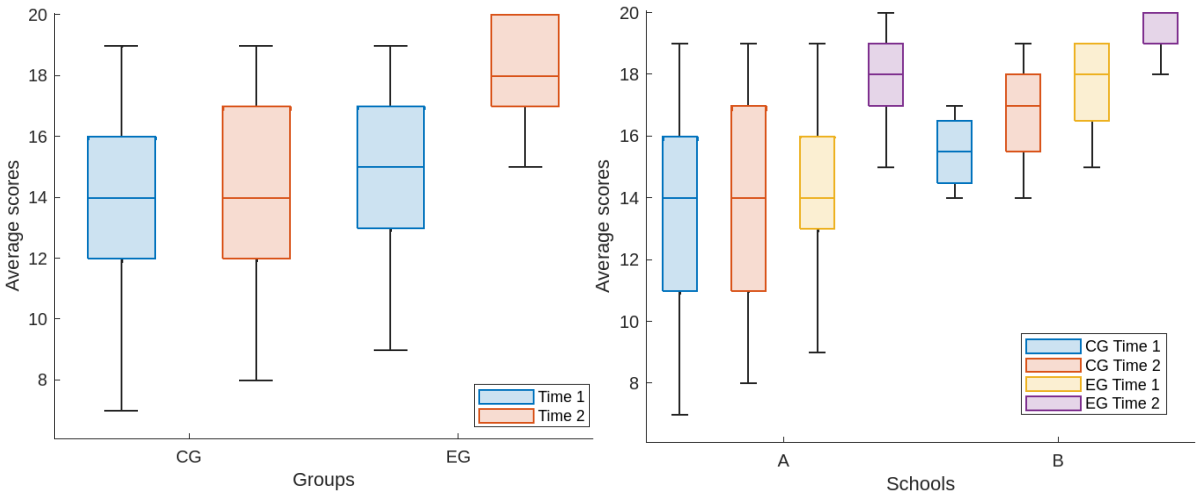
Random Effects	***σ^2***	***Std. Dev. (SD)***
Subject (Intercept)	3.880	1.970
Residual	2.397	1.548

Fixed Effects	***Estimate***	***Std. Error (SE)***	***df***	***t-value***	***p-value***	
(Intercept)	13.1530	0.5248	88.8547	25.061	2e-16	***
Time 2	0.4412	0.3755	70.0000	1.175	0.2441	
EG Group	0.8839	0.5920	99.8667	1.493	0.1386	
School B	1.1999	0.5393	69.0000	2.225	0.0294	*
Time2 : EG Group	3.1378	0.5169	70.000	6.070	5.89e-08	***

*Number of obs. = 144, Number of subj.= 72, *p < .05, **p <.01, ***p <.001*

In addition, Table 3 shows that the treatment was effective in enhancing socio-emotional skills, as evidenced by the significant p-value ($5.89*10^{-8}$) and the correlation between Time 2 and the Experimental group. This is further supported by Fig. 4(a), which shows the improvement of the EG with respect to the CG in terms of median score value.

Furthermore, Table 3 includes another significant value (0.0294) for the variable “School B”. This value indicates that students from School B exhibit superior social and emotional skills compared to their counterparts from School A, regardless of the treatment received. These results are clearly shown in Fig. 4(b), which compares the median scores of the two groups when divided by school affiliation, highlighting the different initial situations. However, it’s essential to acknowledge the study’s limitation, which involves the examination of only two schools, each representing a level of the variable “school”. This limitation makes it challenging to generalize the results to the broader context of public and private schools. Indeed, this discrepancy may be attributed to the specific approach taken by School B, where educational stakeholders (including headteacher, teachers, and parents) place significant emphasis on improving the emotional dimension as a fundamental aspect of children’s growth.



a) *b)*

Figure 4: Comparison of median scores between groups for the socio-emotional abilities test: (a) pretest (Time 1) and posttest (Time 2), and (b) grouped by schools (A, B).

4 CONCLUSIONS

This study shows an innovative use of the Thymio robot in a didactic path and has demonstrated the potential of our approach to foster *school readiness* in children aged 4 to 6 years old. The proposed didactic itinerary is a versatile and comprehensive educational tool that enhances language competencies and social-emotional skills. It also inspires motivation, fosters collaboration, ensures inclusivity, and nurtures a range of valuable attitudes and soft skills. This can empower early learners to develop as responsible and capable individuals in our ever-evolving world.

However, there are some limitations to this study. Firstly, only two schools were considered, which makes it difficult to generalize the results. Consequently, the study could benefit from replication or an extension to include other age groups or populations.

Secondly, the number of sessions could be increased to allow for a more focused and in-depth exploration of the skills being taught, including other skills such as scientific ones.

Nevertheless, the findings of this study suggest several new research avenues. For example, additional materials could be developed to further engage children and enhance their learning. A deeper focus on the materials used in the didactic itinerary would provide a better understanding of children's needs and preferences. Finally, the potential demonstrated by Thymio in the didactic itinerary suggests the possibility of using additional robots into the sessions, thereby creating a more complex and intricate pedagogical itinerary focused on enhancing interactions between children and robots and fostering a broader range of interaction pathways, as suggested in [5,7].

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