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# The impact of educational robot R1 on the development of emotional intelligence in preschool-aged children

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## Abstract

The study investigates the impact of the educational robot R1 on the development of emotional intelligence in preschool-aged children. Employing a convergent mixed methods design with a quasi-experimental pre-test/post-test structure and elements of an embedded case study, the research was conducted in a kindergarten in Athens with 21 children aged 4 to 6 years, including both typically and atypically developing children. Quantitative data were collected through rating rubrics, evaluation sheets, and worksheets, while qualitative insights were obtained via semi-structured interviews and observation. The findings revealed a significant increase in children's emotional intelligence scores across four domains—recognition of emotions, expression of emotions, regulation of emotions, and social skills—following the interventions. Children demonstrated enhanced emotional vocabulary, self-awareness, management of emotions, and collaborative behaviors. The robot served as a socially engaging tool, promoting both affective learning and peer interaction. These results support the integration of educational robotics into early childhood education to foster emotional and social development in inclusive and diverse classroom environments.

**Keywords:** Educational Robotics; Educational Robot R1; Emotional Intelligence; Emotional Skills; Regulation; Primary Education

## 1. Introduction

Innovations in technology have made it easier to incorporate robotics into early childhood learning settings in the quickly changing field of education. Preschoolers' cognitive social and emotional development is being improved using educational robots more and more [1]. While cognitive skills are the focus of traditional pedagogical approaches, recent research indicates that developing emotional intelligence (EI) early on is just as important for a child's overall development and future social and professional success [2]

Emotional intelligence includes self-awareness, self-regulation, social skills, empathy, and motivation. These form the base of a child's capability to relate to others, control emotions as well as build up resilience [3]. A few studies have investigated the mediation role that social robots can play in the emotional and social learning of children [4]. With interactive storytelling along with facial expression recognition and responses to emotional cues robots will be able to provide personalized learning experiences for children which in turn fosters empathy and understanding of emotions [5]

Recent studies show that educational robots are useful in developing young learners' social-emotional competencies [6, 7]. Preschool children who interacted with social robots showed comparatively better formal emotional expression and recognition than those in regular classroom conditions [1]. The integration of robotics increases the ability to communicate emotions as well as cooperation between children [8].

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Even with these encouraging results, there are still obstacles that need to be overcome before robots can be successfully incorporated into early childhood education. Teachers are essential in facilitating children's interactions with robots to ensure meaningful engagement and successful learning outcomes [9]. In addition, more research and regulatory frameworks are required due to ethical concerns about children's attachment to robots and data privacy issues [10].

The purpose of this research is to investigate how the educational robot R1 affects preschool-aged children's emotional intelligence development. The aim is to ascertain whether Robot R1 can be a useful instrument for promoting emotional development in young students by analyzing both quantitative and qualitative data. By providing information for educators' legislators and educational technology developers the findings will add to the expanding conversation about the use of robotics and artificial intelligence in early childhood education.

The research is innovative because it uses the educational robot R1 to help students develop emotional skills which haven't been thoroughly studied in literature. It is an inventive teaching method that blends digital technology and the pedagogical approach for the identification of expression and control of emotions. Along with exploring the possibility of incorporating R1 into the educational process with examples, the paper suggests robotics-based activities and approaches for the development of emotional skills (recognition, expression and management of emotions).

As we wrap up the introduction, we stress the importance of all digital technologies in the field of education and special needs training, which are very productive and effective and facilitate and improve educational procedures, assessment, and intervention through mobile devices that bring educational activities everywhere [54], various ICT applications that are fundamental to education [55–58], and AI, STEM, games, and ROBOTICS that elevate educational procedures to new performance levels [59–69]. Additionally, the development and integration of ICTs with theories and models of mindfulness, meditation, metacognition, and the development of emotional intelligence [70–81] speed up and enhance educational practices and outcomes, particularly in the special needs treatment domain and its practices like assessment and intervention.

## 2. Literature review

### 2.1. Emotional intelligence

The ability to recognize, comprehend, control, and regulate one's own and other people's emotions is known as EI [11]. Emotional intelligence also plays a key role in personal and professional success, as emotional competencies are considered as important as cognitive ones [3]. From then until now, research has been unfolding the dimensions of what comprises EI; emotional stimuli, self-awareness, self-management, social awareness, empathy, social skills, self-actualization, transcendence are some key factors highlighted in bibliography [3, 12]. Studies indicate that higher EI in individuals makes them more adaptive, with better interpersonal relationships and decision-making skills [13]. Educational and professional settings associate EI with effective leadership, resilience and stress management [14, 15].

Furthermore, modern studies investigate how EI can be combined with digital technologies, especially in educational settings and interactions with computers [16]. The creation of emotionally perceptive artificial agents and the implementation of EI training within digital learning environments indicate promising ways to enhance social-emotional skills [17]. Moreover, research has examined the relationship between EI and psychological well-being, demonstrating significant links to reduced anxiety and depression levels [18]. As the area of emotional intelligence progresses, interdisciplinary methods merging psychology, neuroscience, and artificial intelligence lead to a richer comprehension of how EI affects human behavior and decision-making.

### 2.2. Emotional intelligence in preschool-aged children

Preschool children are at the best age for emotional and social growth so they can develop later in life as confident interacting beings. Children at preschool age start to recognize feelings and the skills needed to control these feelings, which then continue to further develop in the years that follow [19]. Research shows that organized programs for learning about emotions greatly improve children's skills in recognizing feelings, showing how they feel, and dealing with social connections [20].

Growing up in environments that are emotionally supportive, like interactive storytelling and role-playing, help children develop their emotional understanding as well as empathy [21]. The other important aspects are the social interactions with peers and caregivers that form the primary experiences for self-regulation and emotional resilience. In this process, the teacher assumes a significant role in leading preschoolers through various emotional experiences and reinforcing positive emotional responses in structured activities [22].

Emotionally intelligent children are increasingly reported in studies to be more socially adaptive, have fewer behavioral problems, and succeed better academically [23, 24]. It is due to this fact that currently most schools around the globe have made it a priority to integrate programs under the heading of emotionally intelligent early education.

### 2.3. Educational robotics and emotional intelligence

The integration of EI in educational robotics has gained significant attention in recent years, as researchers explore the potential of robotic technologies to foster social-emotional learning (SEL) and emotional skills development [25]. Educational robots, like social ones, may be used as interactive learning tools that involve students in an intellectually stimulating yet emotionally engaged learning process [26]. It has been found that robots programmed to recognize and respond to human emotions can support the development of key components of emotional intelligence such as self-awareness, emotional expression, empathy, and emotion regulation [27]. These emotionally intelligent robots may act variously as tutors, peers or facilitators within contexts of collaborative learning for cognitive and socio-emotional development [28].

Furthermore, it is demonstrated that the designing and implementing educational robotics programs can develop students' emotional intelligence through problem solving as well as teamwork and social interaction [29]. Students are required to undertake emotional navigation such as frustration and persistence during robotics activities, thus developing the process of emotional self-regulation [30]. Moreover, coding and programming educational robots enhance perspective-taking and empathy as students are required to consider how their robots interact with others in meaningful and socially appropriate ways [31]. Robotics education, when integrated into AI-focused curricula, can make experiences that support emotional resilience and adaptive learning strategies immersive [32]

The recent developments in artificial intelligence can be coupled with those in affective computing to further expand the place of robotics education in emotional intelligence teaching. Emotion-aware robots having facial expression recognition along with sentiment analysis may render real-time emotional feedback for personalized learning circumstances [33]. Such innovations play a critical role in special education and inclusive learning environments. Robots that are responsive to emotions have proven successful in increasing attention and communication skills of children with autism spectrum disorder (ASD) and other kinds of developmental malfunctions [34]. As educational robotics develops further, interdisciplinary studies involving psychology, AI, and pedagogy will help integrate emotionally intelligent robots in the areas of social-emotional learning and the development of lifelong emotional competence progression.

## 3. Materials and methods

### 3.1. Research methodology

This research was carried out within an embedded case study design [35], which had been combined with a quasi-experimental pre-test/post-test design to evaluate the impact of the educational robot R1 on preschool children's emotional intelligence development. A convergent mixed methods approach has been employed that integrates quantitative and qualitative data for more comprehensive analysis [36]. The quasi-experimental part is framed by a pre-test/post-test structure tests of emotional skills before and after the intervention with no random assignment of participants because this research was conducted in a natural preschool setting [37]. An in-depth examination of the pedagogical context which may elucidate how and why the intervention has effects on the development of emotional intelligence is made possible by the case study.

To gain a comprehensive view of the phenomenon under study, multiple data collection tools have been employed which include evaluation sheets, rubrics, semi-structured interviews, and worksheets. Both quantitative data from evaluation sheets, rubrics and worksheets and qualitative data from semi-structured interviews and observations will provide an understanding of the interventions' efficacy. This is a mixed methods approach wherein both kinds of data are collected at the same time and analyzed in parallel thus allowing for a more nuanced interpretation of the findings [38]. The multiple data sources also improve the reliability and validity of the research while presenting rich contextual analysis within an integrated case study in the educational setting.

### 3.2. Research hypotheses

The overall purpose of the research was to investigate how educational robotics affects the emotional intelligence of preschool children. The research hypotheses were the following:

- H1: Educational robot R1 will contribute to the development of emotional intelligence (recognition of emotions, expression of emotions, management of emotions) of pre-school children.
- H2: The impact of educational robot R1 on the development of emotional intelligence in preschool children will be similar in both genders.
- H3: Educational robot P1 will contribute to the cultivation of social skills in preschool children, encouraging social interaction and cooperation.
- H4: Educational robot P1 will offer different benefits to children typically and non-typically development.
- H5: Children's previous experience with robots will influence their levels of emotional intelligence development compared to children without experience.

### 3.3. Participants

The study was conducted in a kindergarten in a suburb of Athens, Kaisariani, and involved 21 children aged 4 to 6 years (table 1). The sample included 11 boys and 10 girls, representing both typically and atypically developing children, including those diagnosed with autism and ADHD (2 children – one with autism and one with ADHD). A refugee child from Ukraine who was on the classroom staff and attended the inclusion class also participated, thus contributing to the diversity and inclusiveness of the study. The involvement of children from diverse backgrounds enriched the study's findings, highlighting the adaptability of the R1 robot across different learning needs. Written informed consent was obtained from the students' parents to participate in the survey, and their names were coded. A detailed profile of each student was also taken from their teacher.

**Table 1** Demographic characteristics of participants

| **Gender** | | **Age (in years)** | | | | **Socioeconomic Status** | | |
|---|---|---|---|---|---|---|---|---|
| Boys | Girls | 4.5 | 5 | 5.5 | 6 | Low | Middle | High |
| 11 | 10 | 5 | 5 | 3 | 8 | 1 | 18 | 2 |
| 21 children | | | | | | | | |

The study employed a convenience sampling approach, as the participants were selected from a single kindergarten classroom where the intervention was feasible [39]. While the primary sampling method was based on accessibility, the sample also exhibited characteristics of purposive sampling, given the diverse developmental profiles of the children involved, including both typically and atypically developing children, as well as the refugee child. This unintentional but valuable diversity enriched the study, allowing for a broader exploration of how different children interact with the educational robot [36].

### 3.4. Data collection instruments

To assess the intervention's effectiveness, various data collection tools were employed before and after the intervention (table 2).

Initially, there were evaluation sheets that were given before and after the intervention (as a pre/post-test) and contained four parts to be completed. The first part concerned the recognition and expression of children's emotions, where in one column were the emotions of joy, sadness, fear and anger, while in the other column were the means of expression of each emotion, verbal expression, physical and facial expression. Children were asked about each emotion and how it is expressed, and each cell was completed with a tick (✓) or x depending on the children's responses. The above was derived after a series of questions were asked to the students about different situations that evoke emotions e.g. "How do you feel when you lose a favorite toy?" The second part was about the color of emotion. Children were asked to choose a color for each emotion and explain their decision. The third part was about robots and explored the children's state of familiarity with robots, while the fourth part captures children's responses on whether the robots have emotions.

The study, also, employed semi-structured interviews (before and after the interventions) with open-ended questions to assess the children's knowledge, experiences and perceptions regarding emotions and interaction with the R1 educational robot. Given the age of the participants, a flexible and adaptive approach was necessary to ensure that the children were comfortable expressing their emotions and thoughts. There were predefined open-ended questions, but there was freedom to adapt the wording, ask follow-up questions or clarify answers when needed [36]. This approach allowed for a richer exploration of children's emotional knowledge and their overall experience with the robotic system.

Examples of the questions: “What are emotions?”, “Can you tell me some emotions you know?”, “Do you think emotions have something to do with our bodies?”, “A friend of yours is angry. What would you tell him to do to calm down? What do you do when you feel this way? “, “What did you like most and least about robot R1?”.

In addition, there were evaluation rubrics which are an evaluation and observation tool that includes evaluation criteria, performance levels and descriptions for each level. This method allows students to be assessed effectively and objectively in terms of their skills and is a useful tool for the continuous and qualitative improvement of teaching [40]. The rubric was created based on the Teacher's Guide to Descriptive Assessment in Kindergarten by the Institute of Education Policy [41] (Appendix A) to observe and assess children with the help of the teacher before, during and after the interventions. The rubric was divided into two parts. The first part, was to be completed by the teacher, had four axes: expression of emotions, recognition of emotions, regulation of emotions and social skills. The second part was completed by the children to evaluate their experience with R1 robot and their overall experience with the educational activities.

Finally, worksheets were created based on the teacher's guide of the Institute of Educational Policy [41] and on ready-made material adapted to the needs of the intervention. The worksheets were related to the axes research interest and to the interventions. The students completed each worksheet after the activity took place in the context. Because they can't write, the booklets had activities that the children had to circle, draw and match.

**Table 2** Demographic characteristics of participants

| **Instrument** | **Purpose** | **Type** |
|---|---|---|
| Evaluation Sheets | Assess emotional responses and knowledge in robots | Quantitative |
| Rubric | Evaluate emotional intelligence dimensions | Quantitative |
| Semi-Structured Interviews | Gather students' insights on emotions | Qualitative |
| Worksheets | Engage children in activities during the interventions | Quantitative & Qualitative |

### 3.5. Data analysis

The data analysis in this study followed a mixed approach, incorporating both qualitative and quantitative techniques to capture a comprehensive view of children's emotional intelligence development before and after the educational intervention with Robot R1. The qualitative data obtained from the open-ended questions of the semi-structured interviews were analyzed using content analysis approach [42], enabling the identification of patterns and themes related to emotional intelligence. A comparative analysis of pre- and post-intervention responses allowed the researchers to identify shifts in the children's emotional vocabulary, emotional management strategies, and emotional reasoning.

The quantitative data from the rubrics were processed using descriptive statistical analysis. For each child, mean scores were calculated across the four predefined dimensions of emotional intelligence in the rubrics. These scores were analyzed before and after the interventions, and comparisons were made based on gender and educational category (e.g., typically developing children, children with autism or ADHD, refugee status). The same was also done with the evaluation sheets that were given to the children before and after the interventions to examine the progress across sessions.

Data were compared with worksheet results to ensure the validity and reliability of the findings. Visual materials were also analyzed to show the non-verbal cues and emotional expressions, which would make the qualitative analysis deeper. No statistical software was used for the analysis because, in this research, more emphasis is laid on interpretative understanding of data in its context than on statistical inference [43]. Qualitative insights were integrated with quantitative trends to provide a richer understanding of how emotional intelligence evolved throughout the interventions. This has led to a multi-dimensional analysis approach enabled researchers to discern subtle individuals’ variations in the children’s emotional responses and emotional learning processes [36].

## 4. Intervention procedure

### 4.1. R1 educational robot

The interventions were implemented with the R1 educational robot in planned activities designed to foster emotional skills in preschoolers. The R1 robot was programmed to engage children in emotion-centered activities, guided discussions, and playful interactive tasks that required recognition, response and management to emotional signals. The intervention took place in an actual preschool setting, allowing researchers to observe and assess the impact of robotic interaction on children's emotional intelligence development. Sessions took place in a familiar classroom environment, allowing for natural social interactions among the children.

The R1 robot (figure 1) is an educational micro:bit V2 robot created by Polytech specifically for teaching robotics and technology basics. It helps students learn fundamental programming concepts and develop robotic operation skills. The R1 features high-sensitivity servomotors, a high-quality control board, and a yellow car-like chassis resembling a bulldozer [44]. Children can control it wirelessly via Bluetooth using tablets or smartphones or connect it with a USB cable — making it accessible for beginners. At the heart of the R1 is the micro:bit, a small, open-source computer developed by the BBC in 2015 for educational purposes across the United Kingdom (figure 2). The micro:bit comes equipped with a powerful ARM microcontroller, two buttons (labeled A and B), a 5x5 LED matrix that displays text and graphics, plus several sensors including an accelerometer, a magnetometer, a light sensor, a thermometer, and multiple external connection pins. These features let the R1 perform various interactive tasks, from detecting movement to measuring temperature, and responding to light levels.


**Figure 1** The R1 educational robot and its components

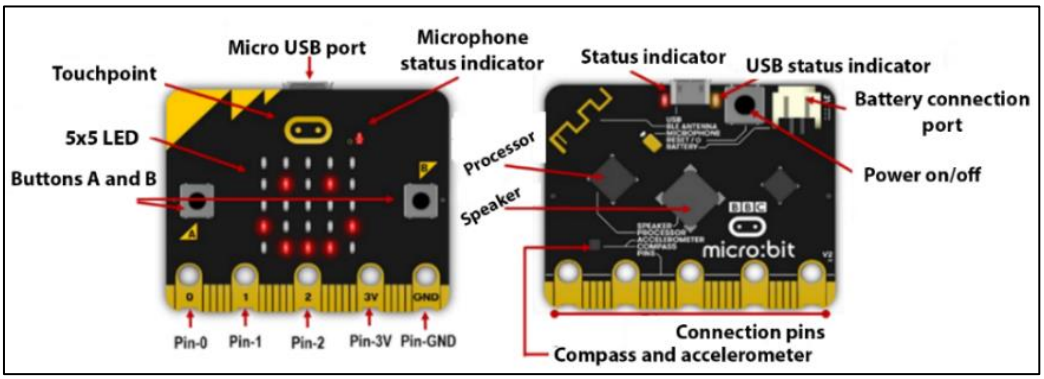


**Figure 2** Micro:bit board with led matrix and sensors

The micro:bit's capabilities make the R1 robot an ideal tool for educational purposes, as it encourages creativity, technological literacy, and digital skills. Through hands-on programming activities, children figure out how to control the robot's movements, respond to sensor input, and execute various actions based on their own code. This practical approach not only enhances understanding of programming logic but also supports emotional and social development through collaborative projects.

### 4.2. Interventions - Activities

This section presents an overview of the fifteen interventions conducted during the research. Each activity was designed to progressively introduce children to the educational robot R1, enhance mostly their emotional skills, and simultaneously develop their social ones. The interventions included interactive activities and semi-structured discussions, all aimed at fostering recognition, expression, and management of emotions. By engaging with the R1 robot, children had a nice and constructive experience while strengthening their emotional skills. The following summaries outline the key objectives and methodologies of each intervention.

1st Intervention - Introduction to the context: The first intervention aimed at creating a safe emotional environment for the children. The activity "Two Truths, One Lie" helped children introduce themselves in a fun and interactive way. According to the activity, the children introduced themselves to the plenary by saying their name and then they stated two elements that characterize them (internal, external) and a lie. The group was asked to discover the lie. At the end of the session, there was only the announcement of the arrival of a "special friend," sparking curiosity and excitement among the children. This activity fostered initial group bonding and set the stage for further engagement with the robot.

2nd Intervention - Observation through movement: Initially, the semi-structured interviews were conducted with the children. Afterwards, a music-movement activity was conducted to observe children's emotional and social responses. Children were guided to mimic different animal movements while music played, encouraging self-expression. At various times the children were asked to pretend to be another animal. At the end, the music gradually started to turn down and the children lay down in a circle, taking deep breaths and doing relaxation exercises, and discussed what they thought of the game, what animals they played in and which one they liked best and why. There was observation with notes during free play. The observations were completed with the completion of the rubric by the teacher, who knows the children and her class and therefore her observation is valid and reliable.

3rd Intervention - Introducing the R1 robot: The aim of the intervention was to arouse interest, curiosity, inner motivation and emotional engagement regarding the robot. Firstly, the evaluation sheets were conducted with the children. Then, the R1 robot was introduced as a "surprise friend." Children were encouraged to guess what it might be and draw their interpretations. Some believed it was a construction machine, while others thought it was a remote-controlled car. This activity lays the foundation for later interactions where children would explore the robot's functions and emotional interactions.

4th Intervention - Class council introduction: The aim of this activity is team bonding, cooperation and teamwork, getting familiar with the robot. The R1 robot was formally presented to the class. The researcher described its capabilities, such as "seeing," "feeling cold or warm," and "responding to touch". A live demonstration was conducted using a tablet to control the robot, which sparked enthusiastic reactions. The children asked playful questions, such as whether the robot could run faster than them or clean the classroom, demonstrating their growing engagement and connection with R1.

**Figure 3** Robot's R1 emotions

5th Intervention - Familiarization with emotions (plus worksheet): The aim of the activity was for the children to observe and express emotions, to get familiar with the robot, to understand how it works, to get familiar with digital tools (such as connecting the robot to a board and choosing the right tool), to identify similarities and differences in the expression of emotions by others. Children worked in groups to use the R1.bit application to explore emotions. They programmed the robot to express happiness and sadness. Crayons, markers and pencils were placed in a basket. Each

child stood up from his/her seat and without looking, used his/her hand to take an object from the basket. The children were asked to express one of two emotions (joy or sadness) and guess what the robot was going to express. Each group noted how many times the robot was sad and how many times it was happy. The robot displayed happiness 13 times and sadness 8 times (Figure 3).

6th Intervention - Expressing and recognizing emotions (plus worksheet): The aim was to express and become aware of emotions with a game of emotion cards presented to the children. 5 emotion cards (joy, sadness, fear, anger and surprise) were placed on the floorboard and after a real social scenario was described, the children had to identify the emotion that suited them and then through the application on the tablet in the remote-control option of the robot to direct it to the correct card on the floor board. For example, when asked, "What do you feel when someone hits you?", one child enthusiastically shouted, "Anger!" and guided the robot to the appropriate card. This activity reinforced their ability to identify and express emotions effectively (Figure 4).

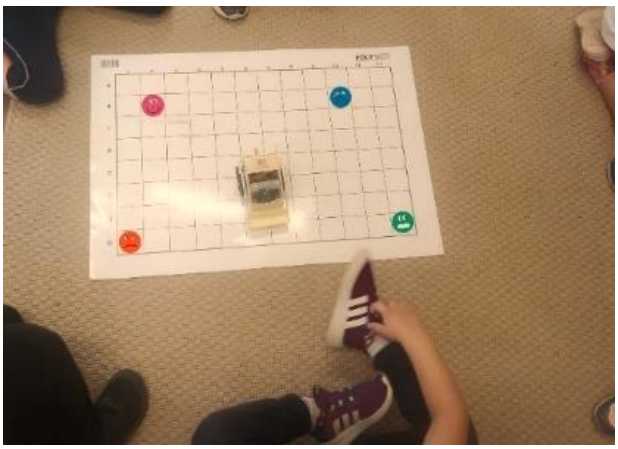

**Figure 4** Emotions game on the floor board

7th Intervention - Rock-paper-scissors with R1 (plus worksheet): The aim of this activity was to entertain, build relationships, understand, accept and manage their emotions. Children played a modified version of rock-paper-scissors against the R1 robot. They competed in teams, with winners advancing to play against the robot. Emotional reactions varied—some children expressed frustration when losing, while others suspected the robot of "cheating." This intervention provided valuable insights into how children handle competition and regulate emotions.

8th - 9th Intervention (plus worksheet) - Emotions quiz (of the R1 application and utilization of the activity board for use of the controller and from the wordwall site “Wordwall | Create better lessons quicker”). The aim of this activity was to develop collaboration skills, to understand the value of teamwork and joint discovery, to develop positive attitudes towards the emotions of others. In this activity, the children were divided into 4 groups and took turns playing both the quiz of the R1 application and the wordwall platform. From the R1 application, they had to find the emotion that the child was feeling in the quiz by choosing between two alternatives. In the wordwall, the degree of difficulty was greater as there were many types of games and many alternatives. The children played a total of four games about emotions which they found very interesting, fun and educational.

10th Intervention - Sensitivity to emotion - Touching the robot and observing what it feels, joy or sadness (plus worksheet). The aim of this activity is to observe emotions, recognize them, understand how the robot works through the touch point and cultivate self-awareness. The children were randomly divided into three groups. The children initially chose a representative from among the group members, who, on a worksheet, which depicted both joy and sadness in writing and visually, marked with a check in the corresponding field the emotion that the robot felt every time a child pressed the touch button on its board. They also wondered why it felt sad or happy every time they touched it and discussed the reasons among themselves (e.g., does it not like us? or did you press it too hard?).

11th Intervention - Robot heartbeat and pulse rate (plus worksheet). The aim of this activity was to manage their emotions, to cultivate their self-awareness, to express themselves, to understand the connection between emotions and physical reactions. A heart appeared on the robot's board, which began to beat. By pressing button A on the robot, the heart beat at a slower rate, while by pressing button B, the heart beat at a faster rate. (Figure 5). Then the researcher told a story titled: "The Little Robot Got Angry". Through the story, it was sought to make a connection between the

heartbeat, our body, and the anger that we can sometimes feel, just like the little robot. Then, strategies were discussed on how the little robot can feel better.

**Figure 5** Heart rate R1 (fast, slow)

12th Intervention - Drawing R1. The aim of this activity was to interact, listen to feelings and express themselves in a creative way. The children were asked to draw the robot R1 by asking them "how would you draw it? Draw it with feeling." No further discussion took place because the aim was to explore the differences from the first drawing the children were asked to do at the start of the school survey. Whereas in the first drawing the robot was depicted as an object/toy, now all the drawings showed an 'animate being' and the robot came to life in all the children's drawings. In particular, it flew with joy and love, which were the most predominant emotions, but it felt anger and sadness because it was going to leave school.

13th -14th Intervention - Discussion in plenary. The aim was to express their emotions and their thoughts, to share, to listen, and to manage their feelings. The discussion was about the feelings the children felt about R1 coming to their school, the new things they learned, their cooperation etc. Also, the evaluation sheet and the rubrics addressed to the children were completed again. Finally, the semi-structured interview followed. Feedback on the activities done at school with the robot.

15th Intervention - Feedback-suggestions and farewell. The aim was to reflect, to express themselves, to discuss, to listen to the opinions and emotions of others, to propose new ideas, to realize what they have learned. The discussion started with a summary of the activities implemented with the children giving their opinion. Next, the children were asked to draw what they were feeling at that moment, and they responded immediately, expressing a variety of feelings and reasons. The drawing was followed by a game whereby the first person holds the end of a bundle and throws the rest to someone else in the circle, saying the emotion they are feeling at that moment. Then the robot said goodbye to them and an attempt was made to carry out a smooth closure in an atmosphere of closeness, security, emotion and warmth.

## 5. Results

The rubric data completed by the teacher, scored on a 5-point Likert-type scale (0 = not at all, 1 = a little, 2 = moderately, 3 = very much, 4 = extremely), showed a notable increase in children's emotional intelligence scores following the intervention with the educational robot R1. Overall, the mean total score for the 21 children across the four emotional intelligence domains (emotion expression, emotion recognition, emotion regulation, and social skills) increased from 2.4 (pre-intervention) to 3.3 (post-intervention) for the group of 21 children, indicating a positive shift in emotional and social behavior. When analyzing each domain separately, "Emotion Expression" increased from a mean of 2.4 to 3.4, "Emotion Recognition" increased from 2.2 to 3.3, "Emotion Regulation" increased from 2.2 to 3.1, and "Social Skills" improved from 2.7 to 3.5.

Further comparative analysis revealed positive trends across gender. Both boys and girls demonstrated improvement across all domains, with boys showing slightly higher post-intervention means in areas such as emotion recognition (3.5 vs. 3.1) and social skills (3.6 vs. 3.5) (table 3). Developmental stage comparisons between toddlers (pre-K) and preschoolers (K) also revealed expected differences (table 4). Preschoolers generally started at higher pre-test scores and demonstrated more pronounced improvement.

**Table 3** Mean total score of rating rubric axes by gender

| **Axes** | **Expression of Emotions** | | **Recognition of Emotions** | | **Regulation of Emotions** | | **Social Skills** | |
|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After | Before | After |
| Boys | 2.5 | 3.4 | 2.2 | 3.5 | 1.9 | 3.0 | 2.6 | 3.6 |
| Girls | 2.3 | 3.4 | 2.1 | 3.1 | 2.5 | 3.3 | 2.8 | 3.5 |

**Table 4** Means of pre-toddler and toddler grading scale axes

| Axes | **Expression of Emotions** | | **Recognition of Emotions** | | **Regulation of Emotions** | | **Social Skills** | |
|---|---|---|---|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| **Pre-toddler** | 2.1 | 3.2 | 1.8 | 3.1 | 1.9 | 2.9 | 2.4 | 3.4 |
| **Toddler** | 2.7 | 3.5 | 2.5 | 3.5 | 2.4 | 3.3 | 3.0 | 3.7 |

In addition, analysis of children with diagnosed learning difficulties highlighted individualized progress showing dramatic post-test increases (table 5). For instance, refugee child improved from 0.5 to 2.0 in emotion expression and from 0.2 to 2.4 in emotion recognition, demonstrating meaningful developmental gains. These quantitative findings support the effectiveness of the R1 robot intervention in enhancing emotional and social skills across a diverse sample of children, including those from neurotypical, neurodiverse, and multicultural backgrounds.

**Table 5** Comparison of before and after evaluation of specific students

| | **Child with Asperger** | | **Child with ADHD** | | **Refugee Child from Ukraine** | |
|---|---|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** | **Before** | **After** |
| **Expression of Emotions** | 3.5 | 4.0 | 2.5 | 4.0 | 0.5 | 2.0 |
| **Recognition of Emotions** | 3.0 | 4.0 | 2.8 | 4.0 | 0.2 | 2.4 |
| **Regulation of Emotions** | 1.8 | 3.3 | 1.0 | 2.5 | 1.3 | 2.3 |
| **Social Skills** | 3.0 | 4.0 | 3.0 | 4.0 | 1.4 | 2.6 |

As for the semi-structured interviews, pre-intervention responses were shorter, more superficial, and often limited to one-word answers, whereas post-intervention responses were longer, more reflective, and emotionally richer. The children appeared more confident in naming, recognizing and expressing emotions and connecting emotional states to behavior or context. For example, before the intervention, 2 children directly named what emotions are and after the intervention 11 children, the indirect description was made by 16 children before the intervention and 10 after the intervention, while regarding the non-existent approach before the intervention it was 3 and after none. In a question whether emotions are related to our bodies before the intervention, 12 children answered affirmatively "yes" and 9 negatively "no". After the intervention, 18 answered affirmatively and 3 negatively, giving examples and parts of the body that are affected. The children who answered negatively were preschoolers.

In addition to the rubrics and interviews, the study incorporated a series of evaluation sheets, child-centered reflection rubrics, and worksheets, which contributed to a more comprehensive understanding of the children's emotional development and their interaction with the educational robot R1. The emotion recognition checklists administered before and after the intervention revealed significant improvement in children's ability to identify and express core emotions—happiness, sadness, fear, and anger—both verbally and non-verbally. Most children were able to demonstrate facial expressions of emotions automatically or with minimal prompting. A playful symbolic activity connecting emotions to colors offered further insights into the children's internal emotional representations. By the end of the intervention, all children confidently associated specific colors with emotions. These associations were faster, more confident, and more imaginative in the post-intervention phase, and appeared to facilitate social bonding and group cohesion, especially during the initial sessions. Children's familiarity with and conceptual understanding of robots also evolved significantly. Before the intervention, most children reported having seen robots only through

screens (television, tablets, smartphones), and only four had encountered a real robot (e.g., robotic vacuum). After the sessions with R1, all children confidently stated they had seen a real robot and could distinguish between real, toy, and screen-based robots. When asked whether robots could feel emotions, responses showed a mix of imagination and cognitive discernment. While some children believed robots had "fake" emotions, most were able to distinguish between authentic human emotions and programmed robotic expressions, demonstrating early critical thinking about artificial emotional behavior.

The children's subjective evaluation of the experience, based on two reflective rubric tools, was overwhelmingly positive. All 21 children reported that they greatly enjoyed the presence of R1 in their classroom and the whole experience suggesting high levels of emotional engagement and social interaction. Nearly all children stated that they learned to recognize emotional states and better understood their own feelings. A majority expressed satisfaction with learning ways to manage difficult emotions such as anger and fear.

Finally, the four emotion-focused worksheets that were used during the interventions supported these findings as well. An analysis of the children's completed activities showed improvement in accurately naming emotions, associating them with appropriate facial expressions or social scenarios, and recognizing how emotions influence bodily reactions. As sessions progressed, children gradually began adopting emotion regulation strategies introduced through the robot, like breathing techniques, distancing methods or simply expressing emotions verbally. They also showed notably more independence and engagement in completing these tasks by the final session. Non-verbal observations reinforced the findings — increased eye contact, better turn-taking, and more empathic gestures (e.g., comforting the robot or classmates). These findings highlight the multi-layered nature of emotional learning fostered using R1 and support the conclusion about the effectiveness of the interventions with the robot.

## 6. Discussion

The results of this study demonstrate the great potential of educational robotics —more specifically the R1 robot—as a meaningful tool for supporting the development of emotional intelligence in preschool-aged children. The combination of quantitative and qualitative data gave an overall picture of emotional cultivation observed during the intervention, underlining not only measurable progress in emotional skills but also deeper internal transformations regarding children recognizing, perceiving, expressing emotions.

Quantitative analysis of rubric data revealed a marked improvement in children's emotional competencies across in the four dimensions assessed: expression, recognition, regulation of emotions, and social skills. The mean scores increased from 2.4 to 3.3 post-intervention indicating that the R1 robot facilitated emotional learning in ways that were accessible and impactful for young learners. Improvements extended across different developmental profiles, including children with autism and ADHD, as well as the refugee child, indicating that the intervention appeared to be inclusive and adaptable to diverse needs. This aligns with previous research emphasizing the benefits of social-emotional learning interventions that incorporate embodied or interactive technologies [45, 46, 25].

Gender and age subgroup analyses further supported these findings, with boys and girls, toddlers and pretoddlers, showing gains that were quite consistent. These improvements thus far suggest that robot-mediated emotional experiences can be effective across a range of early developmental stages in early childhood concerning enhanced emotional learning through multi-sensory, play-based engagement. By the end of the interventions, pretoddlers seemed to display more advanced strategies for the articulation and regulation of emotions, possibly because their cognitive and verbal skills had developed more.

Findings from semi-structured interviews and observational data confirmed the positive trends seen in the quantitative analysis. The responses of the children after the interventions proved to be much more reflective, emotionally sophisticated, and full of content. They substantially increased their ability to name, describe, and relate to emotions, moving from one-word responses to full statements with emotional reasoning. This change in expressive capacity indicates not just cognitive learning but also a form of emotional empowerment, as children appeared more confident in expressing their feelings and understanding those of others.

Evaluation sheets, symbolic color-emotion activities, and worksheets further supported this progress. These tools revealed both the internalization of emotional concepts and the embodiment of emotional behaviors. For example, children's accurate use of facial expressions, gestures, and symbolic representations—such as associating anger with red or joy with yellow—showed that emotional learning had extended beyond language into action and imagination. Furthermore, the children's evolving understanding of what robots are and how they show emotions indicated very much early development of critical thinking and the conceptual differentiation between authentic and artificial affect.

The overwhelmingly positive feedback from the children's own reflections added a metacognitive layer to the results. Their consistent enjoyment, emotional engagement, and recognition of learning outcomes confirm that the robot was not only an effective tool but also a socially and emotionally meaningful presence in the classroom. This finding is important, as emotional bonding and relational learning are core to early childhood education and can amplify the outcomes of any pedagogical approach [47].

The findings of this study allow us to examine the initial research hypotheses considering the evidence gathered through the mixed-methods approach.

H1: Educational robot R1 will contribute to the development of emotional intelligence (recognition of emotions, expression of emotions, and management of emotions) of preschool children. This hypothesis was strongly supported by the data. Quantitative increases in mean scores across all emotional intelligence domains (expression, recognition, regulation) confirm the robot's contribution. Qualitative findings further support this, as children showed greater emotional vocabulary, deeper reflection, and the use of self-regulation strategies. They became more proficient in identifying emotions such as joy, sadness, anger, and surprise and were better able to verbalize their emotional states. These results align with previous studies showing that social robots can effectively support the development of emotional skills in young children [48,49).

H2: The impact of educational robot R1 on the development of emotional intelligence in preschool children will be similar in both genders. The analysis showed improvement in all emotional intelligence domains for both boys and girls, with only slight variations. This suggests that the interventions were equally effective across genders. These findings are consistent with research which found no significant gender-based differences in young children's responses to social robots in emotional learning contexts [50]. Moreover, a study on gender differences in robotics activities supports this study's finding that both boys and girls benefit equally from robotics-based emotional learning [51].

H3: Educational robot R1 will contribute to the cultivation of social skills in preschool children, encouraging social interaction and cooperation. This hypothesis was supported both quantitatively and qualitatively. Social skills showed greatest increase in rubric scores, and observational data confirmed enhanced peer interaction and turn-taking. The interactive activities with the R1 robot fostered collaboration and effective communication among the children. Group tasks encouraged teamwork, idea-sharing, and peer support. Particularly notable was the progress observed in children with autism and ADHD, who showed increased participation and improved social interactions. Similar outcomes were reported in studies where robots facilitated peer communication and social bonding [25].

H4: Educational robot R1 will offer different benefits to children with typical and non-typical development, tailored to their specific needs. It was observed that its use offers various benefits for both children with typical and non-typical development. Data confirmed that children with neurodiverse profiles (autism, ADHD) and the refugee child showed measurable progress in emotional and social domains, although often starting from lower baselines compared to typically developing children. The robot's structured, predictable, and interactive nature may have provided a particularly supportive context for these children. This aligns with previous research emphasizing the potential of social robots in special education [52, 53].

H5: Children's previous experience with robots will influence their levels of emotional intelligence development compared to children without experience. The findings partially supported this hypothesis. Children's familiarity with robots was low at baseline, but their emotional development during the intervention did not appear to be strongly correlated with prior exposure. However, post-intervention responses demonstrated clearer conceptual distinctions between "real" and "simulated" emotional behavior in robots. These results suggest that direct interaction with an embodied robot may have a more significant effect than prior passive exposure, echoing similar conclusions by Belpaeme et al.

Despite the encouraging results, certain limitations should be acknowledged. First, the study was conducted in a single kindergarten setting with a relatively small sample size (N=21), limiting generalizability. Second, the short duration of the intervention may not fully capture the long-term effects of emotional learning through robotics. Third, while the data collection tools were diverse, the absence of standardized and validated emotional intelligence assessments for this age group may affect the precision of measurement.

Future research should consider implementing similar interventions in diverse educational contexts and over longer timeframes to explore sustained impact. It would also be valuable to include a control group and expand the sample to enhance statistical reliability. Furthermore, longitudinal studies could investigate whether early emotional learning

with robots has lasting effects on emotional skills and social integration as children grow. Finally, incorporating parental perspectives could offer a more holistic view of children's emotional development in and out of the school environment.

## 7. Conclusion

This study provides strong evidence that the use of an educational robot R1 can positively influence the development of emotional skills in preschool-aged children. Through a combination of interactive learning, emotional modeling, and playful engagement, R1 supported growth in emotional expression, recognition, regulation, and social interaction. The findings suggest that such interventions are effective across genders, developmental profiles, and cultural backgrounds. The robot was an important technological tool in children's emotional learning development, offering a new perspective for integrating emotional learning into preschool education.

## Compliance with ethical standards

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*Disclosure of conflict of interest*

The Authors proclaim no conflict of interest.

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## Appendix A (Rubric, Before and After the Interventions)

*Rubric for the Experience of Children with Robot R1*

| | | Not at all | A little | Moderately | A lot | Very much |
|---|---|---|---|---|---|---|
| Expression of Emotions | Expresses emotions verbally | | | | | |
| | Expresses emotions non-verbally (body movement/facial expressions) | | | | | |
| Recognition of Emotions | Recognizes emotions | | | | | |
| | Has self-awareness | | | | | |
| | Distinguishes situations that may elicit positive and negative emotions | | | | | |
| | Recognizes social conventions that govern emotions | | | | | |
| | Recognizes that their emotional state may differ from others' | | | | | |
| Regulation of Emotions | Perceives and regulates their emotions | | | | | |
| | Recognizes emotional boundaries and adapts to social situations | | | | | |
| | Responds effectively to anger | | | | | |
| | Handles conflict/disagreement/'failure' situations positively | | | | | |
| Social Skills | Participates in the educational process | | | | | |
| | Participates in group activities | | | | | |
| | Collaborates with others | | | | | |
| | Adapts to the group | | | | | |
| | Understands relationships and interactions | | | | | |

*(Rubric for the Experience of Children with Robot R1)*

- How much did I like that the R1 robot came to school?

- How much did I like that I expressed my feelings?


- How much did I like that I found ways to manage my anger?
- How much did I like that I learned about emotions and know what I feel?
- How much did I like that the robot showed us emotions too?
- It really showed emotions but it doesn't feel them like humans do
- Did you collaborate with your classmates?
- Did you express emotions? (talk about your emotions?)
- Did you learn to recognize emotions?
- Did you find ways to manage your emotions?
- Do emotions affect our bodies?
- Did you observe the robot carefully?