Article

Employing Robotics in Education to Enhance Cognitive Development—A Pilot Study

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Abstract: (1) Background: Info-communication technology (ICT) offers opportunities for innovations in teaching and learning methods, bringing significant changes in the world of pedagogy. The field called *educational robotics* is both a motivational basis for teaching and learning coding and programming, and a tool for linking STEM (Science, Technology, Engineering, and Mathematics) fields. Moreover, it might contribute to the development of cognitive and social skills. The aim of the present paper is to report on a pilot study at the intersection of neurodiversity and educational robotics. (2) Methods: The pilot study was part of a larger project, namely Robotics for the Inclusive Development of Atypical and Typical Children (RIDE). A pre-test/post-test design was used to examine the development of different cognitive processes in sixth-grade students, such as computational thinking (CT), spatial relations, visuo-constructive ability, attention, and reading ability, in relation to a robotics development program employed in the classroom. (3) Results: The results suggest a general improvement on nearly all measures. Specifically, participants' performance improved significantly from pre-test to post-test in the visuo-constructive abilities test, they made significantly fewer reading errors, and improved substantially in their reading comprehension. (4) Conclusions: The RIDE project's curriculum development has resulted in a highly innovative, sustainable, and inclusive package of pedagogical methods, and the pilot research shows promising results regarding the implementation of robotics in education.

Keywords: robotics; cognition; education; computational thinking; spatial relations; visuo-constructive ability; attention; reading ability

1. Introduction

Scientific and technological innovation in the 21st century requires virtually everyone to continuously adapt to the resulting changes in the human-made environment. A key part of this adaptation is the acquisition and development of new competencies. Thinking, problem solving, decision making, learning and creativity, have become interwoven with the use of info-communication technology (ICT). Therefore, enhancing ICT competence and literacy is of central importance and can now be regarded as an aspect of cognitive development [1]. The widespread use of ICT tools in everyday life offers new opportunities for pedagogy including innovations in teaching and learning methods [2].

With the opportunities offered by technology, the need to recognize children's individual needs is becoming increasingly important, as children can follow a number of different learning paths. The neurodiversity approach goes beyond the recognition of typical and atypical development and functioning, and considers the human brain as an ecosystem that offers a diversity of developmental pathways [3,4]. It also focuses on the strengths of the learner and emphasizes the importance of a supportive social environment for development [5]. As we understand better the individual differences of learners and the diversity

of learning pathways, it is becoming increasingly clear that the use of digital technology has great potential for optimized, needs-based, broadly defined teaching-learning processes, within and beyond the context of educational institutions. In Addition, technology not only supports the efficiency of the teaching-learning process, but also develops the learning process itself including the learners' skills, and competencies. Therefore, it has both an assistive and an educational function [6]. The final goal would be to take students from using technology to creating technology [7]. In light of this background, our aim is to report a pilot study at the intersection of neurodiversity and educational robotics.

2. Theoretical Framework

2.1. The Role of Computational Thinking

As the use of ICT becomes more widespread in education, we need to answer the following questions: How can the use of technology help to maximize learning effectiveness? How can technology be adapted to individual needs while supporting differentiation and inclusive education [8–10]? To answer these questions, we have to revert to Seymour Papert's [11] constructionist approach, according to which social and affective involvement by students in the ICT-content will make programming an interdisciplinary tool for learning other disciplines. In his interpretation, computational thinking (CT) has a broad context in which social and affective dimensions are as important as the technical content. The term CT became widely known after the publication of Jeanette Wing's [12] article and is now one of the most intensely investigated concepts in the discourse of coding and robotics in digital education [13]. According to Wing's original definition, CT involves solving problems, designing systems, and understanding human behavior, drawing on the principles of computer science [12]. An excellent area for the development of CT is the rapidly developing field of educational robotics. Educational robotics is both a motivational basis for teaching and learning coding and programming, and a tool for linking STEM (Science, Technology, Engineering, and Mathematics) fields [14]. In some countries, educational robotics and the development of CT is now an integral part of the national curriculum, while in others it is part of other subjects, mainly mathematics [7]. As Seckel and colleagues [15] pointed out, the majority of teachers, regardless of age, gender, and time spent in education, support the introduction of educational robotics. However, it is also important to highlight the inherent difficulties in teaching robotics [7] and to take feedback from teachers into account [16].

There is now a growing body of research confirming the supporting role of robotics in (i) the development of various cognitive functions, and (ii) constructive learning for both typically and atypically developing learners [17–19]. However, most of the literature on the use of robotics in education is descriptive and based on reports by teachers achieving good results using robotics, partly through individual initiatives [18,20,21]. There are also a few studies which did not find any improvement in learning due to the employment of robotics [19,22,23].

Although the use of robotics in education is now widespread, for the most part it is focused on subjects that are closely related to robot programming, robot construction, or mechatronics [14,20,24]. The type of robots used is also important. Most of the available systems offer robots with variable morphology (e.g., Lego, ArTec) giving the user the opportunity to build, plan, and program different kinds of robotic artifacts. These are built in accordance with learning principles derived from Piaget and Vygotsky's theories and were emphasized by Papert and his student Mitch Resnick as well. Resnick—one of the creators of Scratch, a block-based programming language used to popularize and promote programming [25]—states that "Coding is the new literacy!" By learning to code, learners work through knowledge sharing, so they can learn more effectively by working on projects that match their interests, experiment freely, and support the development of their creativity and thinking [26]. Robotics creates the opportunity to combine STEM, coding, CT, and engineering skills, and to develop these areas in a playful and sustainable way. Educational robots allow an integrated, multidisciplinary approach to problems, involving

the interconnection of many technological and social themes. This allows learners to make connections and build knowledge networks encompassing the fields of engineering, physics, and mechanical concepts [27]. Moreover, given the nature of project work, using robots helps group collaboration and self-expression through technological tools [28].

Bascou and Menekse [27] reviewed 119 studies on the use of robotics in STEM education. Their analysis (based on commonalities found in the research methods, results, and subsequent findings) resulted in six thematic headings: (1) General Benefits of Robotics in Education, (2) Knowledge Transfer, (3) Social/Cultural Based Motivation, (4) Creativity Based Motivation, (5) Diversity in STEM, and (6) Professional and Pedagogical Development.

The results under the *General Benefits of Robotics* heading clearly demonstrate that active-learning based pedagogies made possible by educational robots are more effective than classical pedagogy. In terms of *Knowledge Transfer,* educational robots allow learners to make connections between virtual reality and abstract scientific and mathematical concepts and models. Regarding *Social/Cultural Based Motivation*, it is becoming clear that the social and cultural aspects of the target group must be taken into account when generating interest in robotics. The results related to *Creativity-based Motivation* suggest that the creative opportunities offered by the different robotics platforms provide a significant motivational base for learners. In particular, robotics programs that found ways to integrate creative and aesthetic values into the curriculum were effective in increasing students' interest and motivation. The studies that have investigated *Diversity* show that minorities (Latinos, African Americans, women, low socioeconomic status) are underrepresented among engineering and programming professionals. Finally, with respect to *Professional and Pedagogical Development* it can be stated that the integration of robotics into STEM education raises questions about the knowledge and professional skills of teachers, as well as the ways in which institutions are funded. The review reveals significant gaps in teachers' knowledge, skills, and education that may act as barriers to the implementation of robotics [27].

In summary, the development of CT through the effective use of robotics and coding tools, in the area of cognitive skills, and in that of so-called soft human skills (cooperative and social skills), seems to be suitable for achieving the goals of STEM education. As students differ in learning strategies, they may show different preferences for different types of robotic activities [29]. Some children will be active in building robots, others in making robots alive, or in programming, while others will be motivated by using robotics for storytelling.

2.2. The Concept of the RIDE Project

Educational robotics implies new educational paradigms fostering the development of skills which are crucial in the 21st century, such as creativity, cooperative work, innovation, critical thinking, problem solving, among others [7]. The basic starting point of the project—in line with the concept of Rusk et al. [30]—was to provide an opportunity to introduce students with different interests, abilities, and learning preferences to the world of robotics [31].

The project RIDE—Robotics for the Inclusive Development of Atypical and Typical Children—aims to support the development of 8- to 14-year-old students in inclusive groups with the help of robotics. The symbol of the RIDE project is a lovely turtle (see the middle of Figure 1). Our partner's interpretation on the competitive running between the turtle and the rabbit shows that even those who initially started from a serious disadvantage can be equal competitors and they can show their talents if we create the right conditions for them.
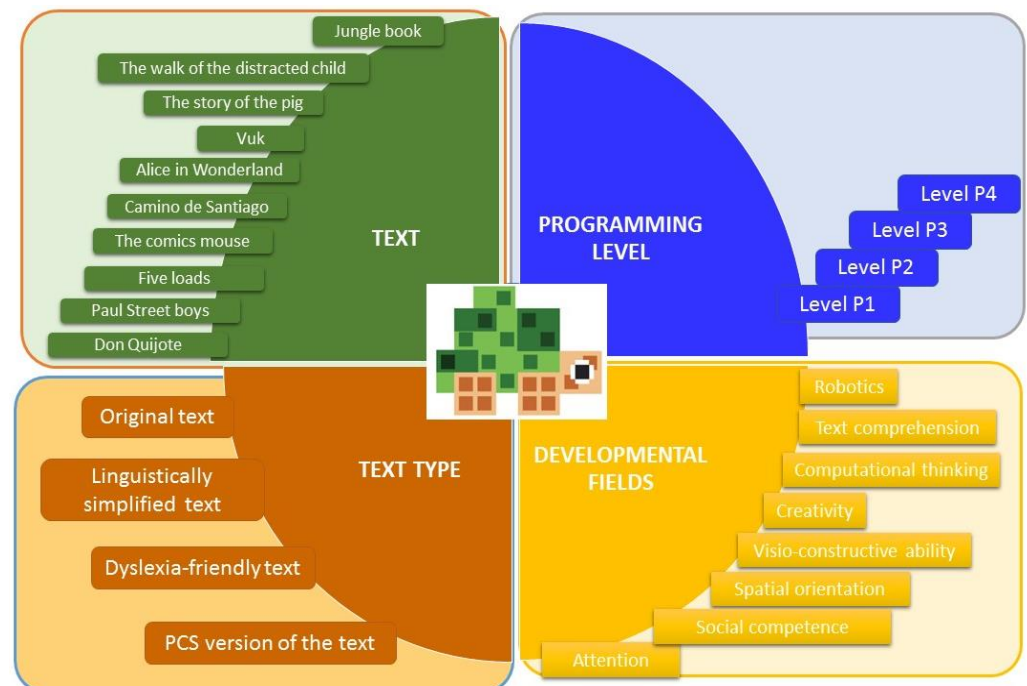
Figure 1. The four-dimensional module matrix of the learning material.

The RIDE learning materials have been developed in the framework of the Erasmus+ project running from 2019 to 2022. Seven organizations from four European countries—Hungary, Italy, Spain, Romania—took part in the project resulting in a four-dimension module matrix. The aim of the RIDE project is twofold: in addition to promoting the love for classic children's and young people's literature, we aimed to develop the cognitive and socio-emotional abilities of the students. The stories used are based on European literary and cultural heritage (e.g., fairy tales, novels, and historical themes).

The aim of the project includes three essential elements: first, the investigation of the developmental potential of children's CT and several other psychological areas (see below) by using robots. Second, to increase the technological knowledge of the teachers involved in the program, to familiarize them with the methodological basics of teaching robotics, and to prepare them for implementation. The third aim is the development of teaching materials that can be implemented in the curriculum.

The developed learning materials used robots built from ArTec robots. This is a modular, colorful, robotic set, which is extremely variable since its building blocks have no top and bottom and can be rotated in any direction. This kit provides an opportunity for teachers to effectively develop their students' skills.

This methodology can be applied to students with special needs, to gifted, and underachieving children, using an inclusive pedagogy approach based on individual needs. The program can be integrated into lessons or can take the form of workshops. We have elaborated a four-dimensional module matrix of the learning material. The first dimension consists of the literary texts themselves. The second dimension of the matrix consists of variants of curricula, worksheets, teacher's guides, model robots, robot programming knowledge base, adapted to the targeted cognitive and social development areas. The third dimension is the level of difficulty of the included literary texts. Each text is divided in 4–6 parts and is suitable for groups of 4–6 children. For each part of the text, several implementation paths are proposed, covering the different developmental fields (taking into account the possibilities offered by the text). The texts are available in 4 different versions: original, linguistically simplified, dyslexia-friendly, and a Picture-Communication-Symbols (PCS) version—the latter is particularly recommended for learners with intellectual disabilities or ASD (autism spectrum disorder). The fourth dimension offers possible robotic solutions and programming levels. For each set of texts, four different levels of robotic solu-

tions are proposed. Consequently, the task can be chosen according to the area needed to be developed and the children's robotics-programming skills and knowledge (see Figure 1).

The project's inclusive methodology allows differentiation according to children's individual needs, regarding both the developmental fields and the robotics/programming skills. Thus, children can work together on the same part of the task, solving tasks of different type and difficulty (some of the student will build the robot from blocks, the other will program that robot and again others build the scenery).

During the sessions, teachers and students alike are supported by a multitude of ideas and templates. Teachers are provided with lesson plans, ideas, and technical guidance for building robots, and variations to help them decide which aspect of development to focus on: text comprehension, spatial orientation, visuo-constructive ability, attention, CT, creativity, social skills, and engineering—giving the opportunity for teachers to select the most adequate area.

The worksheets and templates for students primarily support self-regulated learning, while the teaching materials—adapted to specific developmental areas—inspire children to explore, be creative, and work autonomously in groups. Every story requires five of five sessions to process them.

2.2.1. Lession 1—Warming Up

In this phase students are presented with a short version of the text, which briefly introduces the context they will later explore in more detail. The tasks of this lesson allow students to immerse in the situation of the story without knowing the specific text, to deepen their understanding of some important elements, and to prepare for robot building. This phase involves shaping the characters, building the scenes from the available materials, and having the opportunity to familiarize themselves with ArTec robots. Students can work on a task together, but there is also the possibility to work on different ideas and different areas of development within the group.

2.2.2. Lession 2—The Story

The second phase involves a more in-depth familiarization with the text. Now the aim is to familiarize themselves with the text, to develop reading comprehension, and organize further work in groups. Here the appropriate text type (original, short, dyslexia-specific, PCS version) can be selected. During the processing of the text, students are asked to describe the characters' qualities, their interactions, and to reproduce the storyline. In this phase the students have to decide whether they want to work on one or more robots together as a group or whether the group's product will be the sum of their individual work.

2.2.3. Lession 3–4—Built Your Robot

During sessions 3–4, students create the robotic representation of characters of the given text. They can also use robot building and robot programming ideas for their work. The robotic solutions are indexed, from those involving only mechanical construction to those involving the construction of complex robots, even using partial artificial intelligence (for an example, see Figure 2). Thus, every student has the opportunity to choose the best task that fits them.
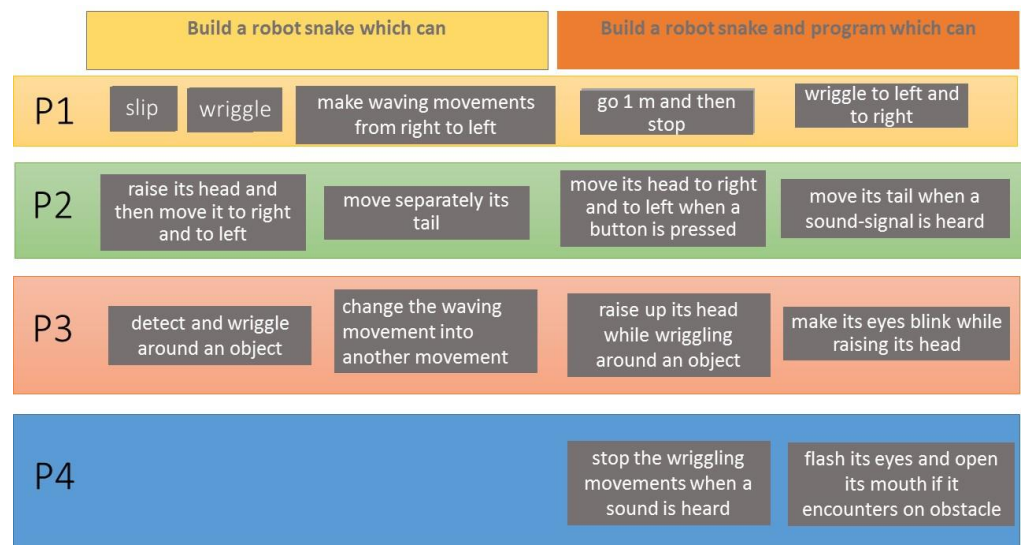
Figure 2. Examples for ideas to build robots and program them at different difficulty levels. In the first column the robots can be built using only mechanical constructions, while in the second column the constructions need programming too. P1, P2, P3, and P4 mark different difficulty levels of programming.

2.2.4. Lesson 5—Show and Tell

The last phase is the closing session when the students—based on the text—have to stage the story. There are several possibilities for closing the project, both by presenting the text itself in different formats and by presenting the workflow itself (for details see Table 1). The latter provides an opportunity to raise awareness of the learning process and learning strategies, and thus to develop metacognitive abilities.

Table 1. Possible options for closing the project.

Options for Presenting the Text	Options for Presenting the Workflow
• live/online presentation of the story to a specific audience • movie in which the robots play the roles • stop motion animation about the building phases of robots • collage, tableau, photomontage, comic strip • presentation of photos, videos, screenshots of the robots	• making-of-film about the project work • collage, tableau, photo montage based on photos taken during the project work and on completed worksheets, cards, templates used • presentation based on photos, videos, screenshots, task sheets, cards, templates

The teachers involved in the project initially participated at a teacher training session. For further details please visit www.riderobotics.eu.

3. The Pilot Study

Given the growing emphasis in research on integrating robotics into education [32] the aim of this work is to present the results of a pilot study on the implementation of the RIDE project. The present pilot study can be considered as being at the intersection of neurodiversity and educational robotics by using an inclusive pedagogy approach based on individual needs and by offering opportunities to develop different skills for both typically and atypically developing children through robotics education. Throughout the project, the tasks were adapted to individual needs, both in terms of input and output. The students entered the task at the level that suited them best (see different text types) and the levels of robotics were constantly adapted to individual needs, so everyone could work at the level they felt comfortable and safe. In this pilot study, we collected pre-test and

post-test measurements, that is, before and after implementing the RIDE project, of the following cognitive abilities: CT, spatial relations, visuo-constructive ability, attention, and reading ability. These measures have been selected on the basis of the areas which the RIDE program is supposed to develop.

In formulating our research question, which was based on the review article written by Bascou and Menekse [27], we focused primarily on the *General Benefits of Educational Robotics*, also taking into account previous research reporting the developmental impact of robotics [13–15]. Consequently, the research question of this study concerned the improvement of skills in the following areas: CT, spatial relations, visuo-constructive ability, attention, and reading ability. Pre-test and post-test data were used to test for changes in the dependent variables corresponding to these areas due to the application of the RIDE curriculum. Given the fact that it was not possible to conduct the pre-test/post-test on a control group due to the COVID-19 lockdowns, we regard the present study as an exploratory one.

4. Methods

4.1. Participants

We examined those children who took part in the RIDE program. Data collection started in September 2021 in different European countries and is still ongoing. Given that the classes from the schools involved in the RIDE project were previously assigned, the sample was not randomly selected. The data presented here were collected in one school in Budapest, Hungary. Pre-test data were recorded in October 2021, and post-tests were collected in May 2022. In the meantime, all students involved in the project have attended the RIDE program sessions held once per week in school settings. Due to the COVID-19 lockdowns, five modules of the originally planned 10 ones could be realized. The final sample comprised one class of 22 students attending the sixth grade, aged between 11.25 to 13.08 years (M = 12.16; SD = 0.65; 9 females). The procedure for data collection using the material described in this study respected all criteria from the GDPR/2018. Moreover, APA ethical standards and the Declaration of Helsinki were followed in conducting this study. Informed written consent from parents or legal caretakers was obtained for all participating children. The participants were informed about their anonymity protection and about the possibility to withdraw from the study at any point. Every participant was given a code for research purposes. The study procedure was approved by the ethical committee of the Free University of Bolzano-Bozen (Protocol number: ROBOAB_Cod_2022_25).

4.2. Procedures

The study was based on a one group pre-test/post-test design. Although initially a double-blind pre-test/post-test design was planned, this could not be realized because of the COVID-19 lockdowns. In both the pre-test and post-test conditions, children were tested individually as well as in group by research assistants. The individual assessments were conducted in a silent room in the school building and took approximately 20–25 min for each participant. The group assessments took place on a different day in the participant's classroom and lasted about 20 min.

4.3. Materials

4.3.1. Beaver Cards

The Beaver Cards are the Hungarian version of Bebras Cards and were used in this study to evaluate CT. These cards were developed by an international educational community in order to attract youngsters to computer science. There is an annual competition organized in more than 50 countries for primary and secondary education students. The tasks based on grades and ages are split into five categories: Mini (grades three to four, ages 8–10), Benjamin (grades five to six, ages 10–12), Cadet (grades seven to eight, ages 12–14), Junior (grades nine to ten, ages 14–16), and Senior (grades eleven to twelve, ages 16–18). The tasks are composed in a manner that they can be solved without any previous computer

sciences knowledge [33]. In this research we used the tasks from 2020 designed for the Benjamin category, which is for fifth to sixth grade students aged between 10–12 years. The task contains 18 problems at three levels of difficulty (easy, middle, and difficult). Given that these tasks are elaborated for a competition, in our research we did not apply the whole battery. Our main goal was to identify the training effects on CT and not to create an order based on the results. Therefore, we selected six tasks: two from the easy category and four from the middle category. The tasks were administrated individually, and the original scoring was used: in the easy category, 6 points were given for each correct response and −2 points for each incorrect response; in the middle category each correct response was worth 9 points and each incorrect response, −3 points, so the total scores ranged between −16 and 48 points.

4.3.2. Spatial Relations Test of Woodcock Johnson III: Tests of Cognitive Abilities (WJ TEST)—Hungarian Version

The WJ Test, based on the Cattell–Horn–Carroll (CHC) theory, is a norm-referenced test of intelligence covering a wide range of cognitive skills. Including a total of ten tests, it returns a General-Intellectual-Ability (GIA) score as well as individual standard scores for each of the tasks used. In this study we used the Spatial Relations subtest in order to measure spatial orientation skills. To achieve correct responses the subject has to mentally rotate different shapes. The subtest contains 33 tasks with increasing difficulty. Each correct answer is worth 1 point, each incorrect answer 0 points. The test recording is interrupted after 6 consecutive 0-point answers. The tasks were administered individually.

4.3.3. Construction Test from Dean-Woodcock Sensory Motor Battery (DWSMB)

The DWSMB consists of 18 individual subtests measuring two major sections: sensory and motor functions. In our study we applied the Construction test belonging to the motor assessment in order to capture visuo-constructive abilities. During the task, the subject first has to copy a standard cross presented by the examiner; following that, he/she has to draw a clock showing 2:40. In both cases, scoring is based on pre-defined criteria (1 point if met, 0 point if not met), with a maximum of 10 points for the cross and 12 points for the clock [34]. In our research we also recorded the time needed to complete the tasks. The tasks were administrated individually.

4.3.4. Bell Test

The Bell test is a cancellation test originally developed to assess visual neglect and adopted in the present study to evaluate participant's selective and focused attention. Participants were required to detect and circle 35 pseudo-randomized bells among 315 distracters. These were arranged in seven columns—three on the left side of the sheet, three on the right side, and one in the middle. The total number of circled bells and the time needed to complete the task was recorded [35]. Given that our main aim was to capture the development of the participant's visual selective and focused attention we recorded the number of circled bells and the number of false alarms (other circled objects) marked in 60 s per sheet. The test was administered in group.

4.3.5. Text Comprehension

The reading test initially developed by Meixner and revised by Sipos contains 50 vowels, 50 consonants, 50 two-letter syllables, 50 three-letter syllables, 50 words and two 100-words texts with questions assessing text comprehension. Two parameters were recorded: the time needed to complete the task and the number of errors [36].

5. Results

A series of *t*-tests for matched samples were conducted for each measure at pre-test and post-test in order to evaluate developmental differences between the two administration points in the various cognitive areas. An alpha level of 0.05 was used and Cohen's *d* was

reported as effect size. Table 2 shows descriptive statistics for each measure including means and standard deviations at pre-test and post-test, and statistical differences between the two administration times. The results showed that participants' performance improved significantly from pre-test to post-test in the visuo-constructive abilities (DWSM) test, and specifically in the cross time. Moreover, at post-test participants made significantly fewer reading errors and improved substantially in their reading comprehension by giving significantly less inaccurate responses and giving tendentially more accurate responses in the reading comprehension task. Finally, participants gave more accurate responses at post-test compared to pre-test in the spatial relation (WJSR) test, although this result was only marginally significant. In all other measures we found no significant differences between pre-test and post-test, although an inspection of participants' mean scores suggested a general improvement in nearly all remaining measures, with the exception of the selective and focused attention (Bell) test.

Table 2. Means (and standard deviations) for each measure and differences between pre-test and post-test.

	Pre-Test	Post-Test	t	df	p	Cohen's d
Variables	**M (SD)**	**M (SD)**				
Beaver cards						
Scores	14.18 (15.20)	17.71 (15.47)	−1.021	20	0.319	−0.223
WJSR Test						
Spatial Relation Test	19.82 (3.62)	21.29 (3.51)	−1.751	20	0.095	−0.382
DWSM						
Cross points	7.86 (1.21)	7.90 (1.41)	−0.404	20	0.691	−0.088
Cross time (in sec)	15.37 (4.33)	10.86 (3.75)	5.031	20	0.000	1.098
Clock points	9.73 (2.96)	10.19 (2.87)	−0.140	20	0.890	−0.031
Clock time (in sec)	87.39 (57.62)	70.38 (27.20)	0.999	20	0.330	0.218
Bell Test						
Accurate responses	97.55 (12.48)	97.17 (21.99)	0.164	15	0.872	0.041
Reading comprehension Test						
Reading time (in sec)	298.47 (79.39)	276.37 (32.16)	1.228	9	0.251	0.388
Reading errors	17.07 (12.51)	14.62 (8.30)	3.115	9	0.012	0.985
Reading comprehension accurate responses	2.50 (1.35)	4.37 (1.31)	−2.177	9	0.057	−0.688
Reading comprehension inaccurate responses	1.57 (1.02)	0.25 (0.45)	3.881	9	0.004	1.227

6. Discussion

The main objective of the RIDE project is to build a sustainable bridge between the worlds of technology and education, while ensuring the development of self-regulated learning [37] and taking into account learners' neurodiversity [38]. The aim of the present study, realized within the RIDE project, was to assess the measurable changes detected on the targeted development areas obtained by processing the text with robotics. The following areas were investigated: reading and reading comprehension, visuo-constructive ability, attention, spatial orientation, and CT.

Unfortunately, due to the COVID-19 pandemic, the originally planned double-blind pre-test/post-test research design could not be implemented. The pre-test/post-test results showed significant improvements in several areas. In particular, there were significant changes in reading accuracy, text comprehension, and visuo-construction skills. We suppose that this result can be attributed to the fact that the children were more motivated to process the texts in depth because of the robotics. During the project work, they could work with several types of texts according to their individual needs, and the processing was also supported by tasks and worksheets related to the text. According to teachers' feedback, there have also been cases of children whose curiosity was so aroused by particular texts that they wanted to read them in its entirety. The improvements in the execution time of the visuo-constructive test and the marginally significant improvements in the spatial orientation test (WJ—Spatial relations) may be explained by the specificity of the ArTec robots. Indeed, the building blocks have no top and bottom and can be rotated in any direction, thus the construction process itself strongly uses these skills. In all other measures, there were no significant differences between pre-test and post-test, although the results suggest a general improvement in nearly all remaining measures, with the exception of the selective and focused attention (Bell) test. We found little previous data that have quantitatively examined the impact of robotics on the development of attention. Previous research [39] has also failed to clearly demonstrate the impact of educational robotics on the development of attention. In the present study, we did not observe any significant change in the area of focused and selective attention. However, the results should be interpreted with caution since the original developed plan had to be reduced due to the COVID-19 pandemic. It is likely that, if the modules had been scheduled as originally conceived, the results would have been different from those obtained in the present study.

Nevertheless, the present study adds a valuable new approach to the field of educational robotics. Previous research has mainly focused on the effects of educational robotics on STEM and CT. The strength and novelty of this project was to connect educational robotics with literature and the results of the present pilot study clearly showed that besides sciences, robotics can also be employed to improve humanities. Indeed, we could not find any previous research examining the impact of robotics on wider areas, and we could not find any previous study on the impact of ArTec robots. Notwithstanding, the results of our pilot study are in line with previous outcomes demonstrating the effectiveness of robotics in educational settings [18,20,21,27]. Although our research focused primarily on the *General benefits* of Educational Robots, it can be also linked to several other thematic headings described by Bascou and Menekse [27]. The RIDE modules contribute to constructivist learning, as learners develop new knowledge through exploration, discovery, and cognitive associations with previous experiences. While most studies have demonstrated the cognitive and motivational benefits of using robots, in agreement with Bascou and Menekse [27], we have to remark that without competent teachers and effective methodologies, these beneficial effects remain theoretical. To integrate educational robotics in schools, we need to find ways to train teachers effective methodologies. The RIDE project presented in this work might be one useful tool to reach this goal.

7. Limitations and Perspectives

The present pilot study has several limitations. The main limitation is that the originally planned double-blind pre-test/post-test research design could not be implemented. Therefore, the effects of biological maturation and education could not be disentangled. Moreover, besides the small sample size, the results were obtained from one single class which makes generalizability difficult. Thus, future research should reveal the developmental changes captured in the mentioned areas in a more reliable way. Finally, as Bascou and Menekse's [27] review pointed out, minorities (Latinos, African Americans, women, and low socio-economic status) are under-represented in the professional fields of engineering and programming. Consequently, future studies on the effects of educational robotics

should include more diverse populations and especially people with special educational needs, which also represent a minority group.

8. Conclusions

The RIDE project's curriculum development has shown to include a highly innovative and inclusive package of pedagogical methods. While taking into account Valko and Osadchy's [32] finding that teachers today have very little material to prepare robotics lessons, this project also seeks to fill this gap by offering free online learning materials for the integration of robotics into education. Moreover, the promising results of this pilot study filled another gap in the literature, namely the use of a more comprehensive approach in the investigation of the effects of robotics in education by including a broad spectrum of psychological functions. Our results suggest that combining literacy and robotics might represent an effective and sustainable way to support children's development in education.

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