Educational Robotics in Primary Education

Maria Anna Jedina, Lilla Korenova, Katarina Zilkova
marianna.jedina@gmail.com, korenova@fedu.uniba.sk, zilkova@fedu.uniba.sk
Faculty of Education
Comenius University Bratislava,
Slovakia

Abstract: *This article explores the educational potential of the programmable robots BlueBot and Robot Emil in developing computational and algorithmic thinking among primary school pupils. Drawing on contemporary curriculum reforms and empirical classroom research, we compare both tools through the lens of inclusivity, pedagogical accessibility, and their impact on logical reasoning, collaboration, and problem-solving. BlueBot, with its tangible, floor-based programming environment, fosters early intuitive understanding of sequencing, spatial orientation, and teamwork. Robot Emil, developed by a team at Comenius University, offers a screen-based, progressively structured environment that supports the development of higher-order computational skills, including abstraction and debugging. The article synthesizes findings from intervention studies, highlighting gains in students' algorithmic thinking as measured by pre- and post-test assessments. We discuss practical classroom strategies, the "low floor, high ceiling" design of both robots, and their relevance for mathematics and science integration. The paper concludes that both BlueBot and Robot Emil are effective, inclusive tools for cultivating 21st-century competencies, and provides recommendations for their successful implementation in primary educational settings.*

1. Introduction

The expansion of digital technologies demands that education cultivate cognitive skills beyond literacy and numeracy. [3] Algorithmic thinking—formulating problems and solutions as precise sequences—is central to computational thinking and supports adaptability in a technology-driven context. [12] As digitalization intensifies, problem-solving increasingly relies on structured reasoning, decomposition, pattern recognition, and abstraction. [5],[9] Educational reforms in Europe, including Slovakia, emphasize early development of higher-order thinking and digital competencies, with Mathematics and Informatics curricula fostering logical reasoning, debugging, and algorithm construction. [10],[6] Appropriately integrated technologies, including educational robots and visual programming environments, enhance abstract concept understanding, motivation, and practical application. [13],[8] Teaching algorithmic thinking remains challenging [4]; child-oriented tools that visualize processes and provide immediate feedback mitigate cognitive load while supporting reasoning. [2] This study investigates two such tools—BlueBot and Robot Emil—in Slovak Grade 4 classrooms, using a pre-test/post-test design over eight activity units per tool. [7]

2. Algorithmic thinking

Algorithmic thinking, defined as "the ability to construct a solution to a problem through systematic logical steps" [5], involves abstraction, problem analysis, iterative solution testing, data structuring, and generalization [9]. It can be developed in pre-primary and primary education using suitable tools and programs [4]. Abstraction, still emerging in 4th-grade students, underpins concept formation and cognitive reasoning [8]. Despite this potential, pupils often struggle with abstraction in programming tasks [4],[6] hence, this study employs child-oriented environments—Blue-Bot and Robot Emil—adapted to their cognitive level.

3. Educational Robotics in Primary Education: The Use of Blue-Bot and Robot Emil

The integration of educational robotics in primary education has gained considerable attention over the past decade due to its potential to cultivate computational thinking, foster problem-solving skills, and nurture collaborative teamwork among young learners.[3], [13] Among the most prominent tools in this area are Blue-Bot and Robot Emil, both designed to meet the developmental needs of primary school pupils. Their child-friendly interfaces and hands-on approaches allow children to experiment with programming concepts in an accessible, playful, and meaningful way. [11] This trend is not limited to Slovakia; it reflects a broader global movement in which robotics is increasingly recognized as a transformative educational tool across diverse contexts. [14], [15] Systematic reviews and meta-analyses further confirm that educational robotics provides moderate but consistent benefits for the development of STEM competences in primary education and is increasingly positioned as a core element of 21st-century skill-building. International evidence demonstrates that similar tools—ranging from floor robots to visual programming environments—have been successfully used in Europe, Asia, and Latin America to strengthen computational thinking, social-emotional learning, and creativity. Studies also emphasize the importance of inclusive approaches, where low-threshold, high-ceiling designs enable all pupils, regardless of background, to actively participate and succeed in robotics-based learning. [16], [17]

BlueBot in Primary Education – Activities and Didactic Goals 3.1 BlueBot is a compact, programmable floor robot designed to facilitate embodied learning and to foster an intuitive comprehension of algorithmic principles. The activities used in our study were developed to build pupils' abilities to navigate space, use alphanumeric coordinates, design step-by-step programs, and test and debug solutions. Each activity was designed with specific didactic goals:

1, Orientation on the mat. Pupils learn to identify and name coordinates (A1, B3), strengthen spatial awareness and the ability to translate symbolic positions into real movement commands. 2, Linear programming with shapes. The goal is to practise sequencing, logical commands ordering, and anticipating the robot's trajectory before execution. 3, Programming with conditions. Pupils develop plane making skill, logical reasoning, and decision–making by adding constraints (e.g., visiting certain points before reaching a target). 4, Task creation and debugging**.** The aim is to foster critical thinking and metacognition – pupils design a solvable task for peers and verify its correctness, learning how to analyse errors and correct them. These activities gradually introduce key aspects of algorithmic thinking: decomposition, pattern recognition, abstraction, and debugging. [9] Working in teams encourages collaboration, communication, and shared responsibility for problem-solving outcomes.

Robot Emil in Primary Education – Activities and Didactic Goals 3.2 Robot Emil, developed under Professor Ivan Kalaš et al. at Comenius University, provides an accessible visual programming environment. Activities are structured into four progressively challenging "worlds": Green – sequencing simple commands; Blue and Yellow – symbol recognition, pattern completion, and sequence continuation; Red – loops and command optimization to enhance planning, testing, and efficiency. Didactic objectives include systematic thinking, algorithmic confidence, attention to detail, and perseverance through iterative debugging (Blaho, Kalaš & Moravčík, 2021). Collaborative work fosters explanation of reasoning, strategy comparison, and peer feedback. Integrating these structured activities builds algorithmic thinking, communication, creativity, and teamwork. Starting with Blue-Bot supports intuitive command-action understanding, while Robot Emil deepens abstraction, introduces loops, and reinforces problem decomposition. Teachers should clarify learning outcomes, allow reflection, and link robotics tasks to mathematics, science, and real-world problem-solving.

4. The Methods and Research Questions

The development of algorithmic thinking in primary school pupils is strongly influenced by the learning tools and environments provided to them. [9], [13] However, empirical evidence comparing the impact of physical robotics and digital visual programming tools on young learners remains limited, particularly in the Slovak educational context. This study seeks to address this gap through a mixed – methods action research design.

Research Problem 4.1. Despite the recognized importance of algorithmic thinking in early education, there is little evidence on which types of learning tools (tangible robots vs. screen – based programming) are most effective for developing these skills in pupils aged 9–10 years. Teachers often lack clear guidelines on selecting appropriate tools and designing structured, age–appropriate activities that foster sequencing, abstraction, debugging, and collaborative problem-solving. This research responds to the following problem:

How can educational robotics and visual programming environments be used effectively to develop algorithmic thinking in primary school pupils, and which approach demonstrates greater learning gains in measurable outcomes?

Methodology 4.2 The research involved 31 pupils in Grade 4, divided into two groups of 15 and 16 learners. Both groups took a Pre–test assessing algorithmic thinking skills (maximum score: 20 points). Group 1 worked with BlueBot, a physical robot allowing embodied navigation and tangible interaction with commands. Group 2 worked with Robot Emil, a visual programming environment offering structured, screen-based challenges. Each group participated in eight progressively complex activities over the course of one month, focusing on decomposition, sequencing, pattern recognition, and debugging. At the end of the intervention, all pupils completed a Post–test with identical maximum score (20 points).

In addition to quantitative test data, qualitative observations were collected throughout the activities, focusing on pupils' problem-solving strategies, collaboration, engagement, and challenges in abstract reasoning. These observations provided additional insight into the learning process and informed practical recommendations for teachers.

5. Research Questions

This study aimed to address the following research questions:

1. **RQ1:** Which group of pupils demonstrates greater progress in algorithmic thinking skills, measured by the difference between Pre-test and Post-test scores?
2. **RQ2:** How do the two tools (BlueBot vs. Robot Emil) influence pupils' ability to plan, sequence, and debug algorithms during collaborative problem–solving activities?

3. **RQ3:** What specific difficulties and misconceptions do pupils encounter when working with physical robotics versus screen–based programming environments?
4. **RQ4:** What pedagogical strategies and activity designs can teachers adopt, based on the observations, to improve the development of algorithmic thinking in primary school classrooms?

By addressing these questions, the research aims to generate evidence–based recommendations for the effective integration of educational robotics and visual programming tools into primary education, supporting national curriculum goals for computational thinking and problem-solving.

6. Tools and Intervention

Blue – Bot 6.1 We prepared eight complex activity units for Grade 4 pupils, each consisting of graded tasks systematically organized by difficulty and metacognitive requirements. Pupils gradually learned to operate Blue-Bot. The main goal was to develop algorithmic thinking through activities focused on mastering orientation on the mat, understanding alphanumeric coding, and programming Blue-Bot to navigate specific positions. Tasks included following instructions, creating and testing their own tasks, detecting errors, and iterating solutions. Pupils worked in groups of six with rotating roles—programmer, recorder, and tester—so that all members experienced each role; tasks were grouped in series of 3 or 6 to ensure each pupil could practice all roles. Initial activities emphasized basic orientation and coding, intermediate tasks involved guiding the robot under given conditions, and final tasks required creating and solving peer-designed challenges while anticipating and correcting possible errors. Through these units, pupils developed metacognitive skills, teamwork, problem analysis, task creation and recreation, iterative debugging, abstraction, and interdisciplinary understanding. Materials included Blue-Bot, mats with geometric shapes or transparent squares, printed assignments, pencils, erasers, a flat smooth floor, and a robot charger.

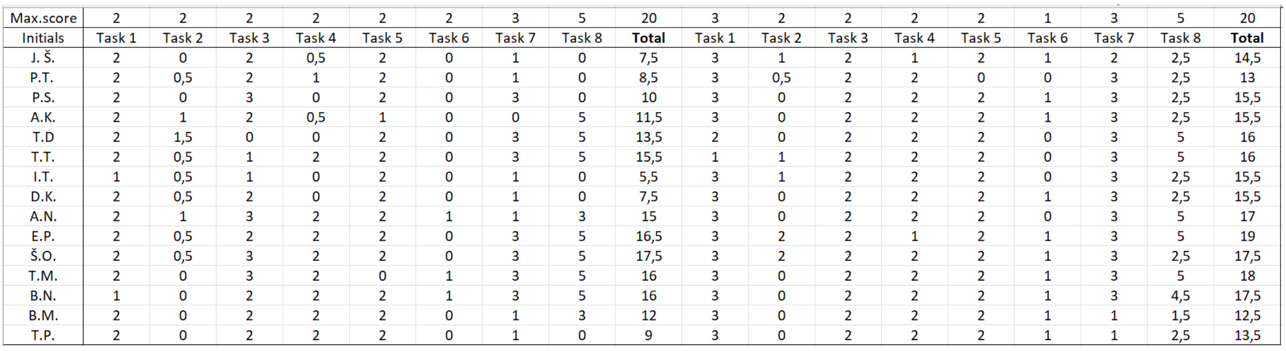
Robot Emil 6.2 We selected eight units from the Robot Emil program to develop pupils' algorithmic thinking. The main goal was to introduce pupils to the interface, enable functional use of commands, perform tasks, and explore possible solutions. A further objective was to engage students in iterative learning by programming in cycles, detecting errors, and considering alternative strategies. Pupils begin in the Green World with Units A and H, focusing on basic movements and sequencing commands to complete scripts. In the Blue World, Unit D introduces new commands and interface functions, helping pupils navigate and use these options effectively. The Yellow World involves Units D and F, with faster pupils progressing to Units E and G, combining pattern elements, spatial orientation, and applying previously learned commands, including printing specific elements. Finally, in the Red World, Units F and B require pupils to combine commands into cycles and sequences, solve complex tasks involving multiple commands, and verify functionality.

During all activities, pupils work collaboratively in pairs or groups, planning tasks, anticipating outcomes, sequencing commands, evaluating execution, detecting errors, and refining solutions. They assess the success and functionality of their programs, correct mistakes, and consider alternative approaches. These experiences foster algorithmic thinking, metacognitive skills, teamwork, and the foundational competencies necessary for future programming tasks.

5. Data Analysis

The collected data from the pre-test and post-test assessments were analyzed quantitatively to evaluate the progress in algorithmic thinking achieved by pupils in both groups during the one-month intervention. Each test consisted of eight tasks, with a maximum total score of 20 points. The pre-test measured pupils' initial skills in sequencing, pattern recognition, and problem decomposition, while the post-test, administered after completing the eight activity units, assessed changes in their ability to plan, execute, and debug algorithms.

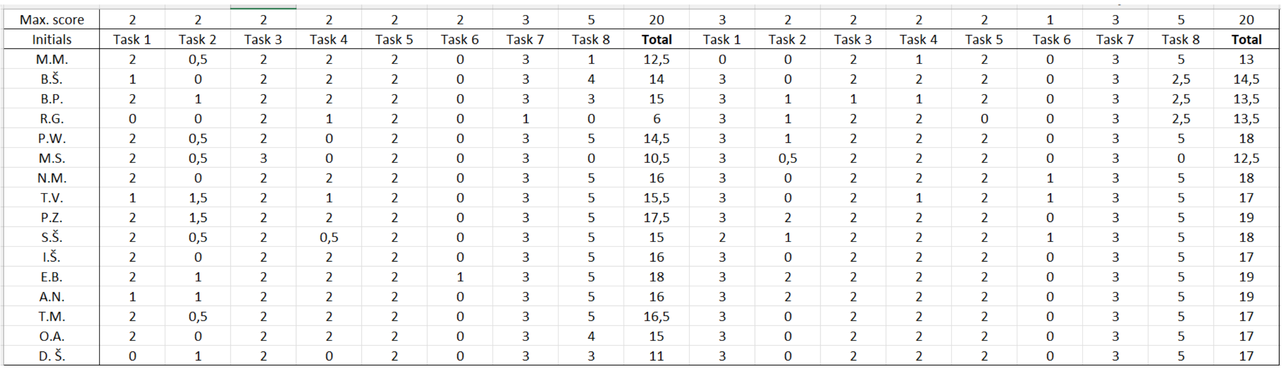
Group 1 – Blue-Bot 5.1 Group 1 consisting of 15 pupils working with the Blue-Bot robot, achieved a mean pre-test score of 11.50 points (≈57.5% of the maximum). The mean post-test score increased to 14.87 points (≈74.3%), resulting in an average gain of 3.37 points. All pupils either maintained or improved their performance, with 13 pupils showing positive gains and 2 pupils maintaining the same score. The overall group sum increased from 172 to 223 points, indicating a consistent improvement across most pupils. Gains ranged from 0 to 10 points, with a median of 2.5 points, suggesting that nearly all pupils benefitted from the hand–on, collaborative activities with the tangible robot. This aligns with earlier studies indicating that physical manipulation of programmable devices supports concrete understanding of algorithms and debugging strategies.



Max.score	2	2	2	2	2	2	3	5	20	3	2	2	2	2	1	3	5	20
Initials	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	**Total**	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	**Total**
J. Š.	2	0	2	0,5	2	0	1	0	7,5	3	1	2	1	2	1	2	2,5	14,5
P.T.	2	0,5	2	1	2	0	1	0	8,5	3	0,5	2	2	0	0	3	2,5	13
P.S.	2	0	3	0	2	0	3	0	10	3	0	2	2	2	1	3	2,5	15,5
A.K.	2	1	2	0,5	1	0	0	5	11,5	3	0	2	2	2	1	3	2,5	15,5
T.D	2	1,5	0	0	2	0	3	5	13,5	2	0	2	2	2	0	3	5	16
T.T.	2	0,5	1	2	2	0	3	5	15,5	1	1	2	2	2	0	3	5	16
I.T.	1	0,5	1	0	2	0	1	0	5,5	3	1	2	2	2	0	3	2,5	15,5
D.K.	2	0,5	2	0	2	0	1	0	7,5	3	0	2	2	2	1	3	2,5	15,5
A.N.	2	1	3	2	2	1	1	3	15	3	0	2	2	2	0	3	5	17
E.P.	2	0,5	2	2	2	0	3	5	16,5	3	2	2	1	2	1	3	5	19
Š.O.	2	0,5	3	2	2	0	3	5	17,5	3	2	2	2	2	1	3	2,5	17,5
T.M.	2	0	3	2	0	1	3	5	16	3	0	2	2	2	1	3	5	18
B.N.	1	0	2	2	2	1	3	5	16	3	0	2	2	2	1	3	4,5	17,5
B.M.	2	0	2	2	2	0	1	3	12	3	0	2	2	2	1	1	1,5	12,5
T.P.	2	0	2	2	2	0	1	0	9	3	0	2	2	2	1	1	2,5	13,5

Table 5.1 Comparison of Pre–Test and Post–Test Scores for Group 1

Group 2 – Robot Emil 5.3 Group 2, consisting of 16 pupils working with the Robot Emil visual programming environment, started with a higher mean pre-test score of 13.63 points (≈68.1%). However, their mean post–test score only slightly increased to 14.31 points (≈71.6%), resulting in a mean gain of 0.69 points. Thirteen pupils improved their scores, one pupil maintained the same result, and two pupils scored lower on the post–test, leading to a total group increase from 218.5 to 229 points. Gains ranged widely, from –15 to +7.5 points, indicating greater variability in learning outcomes within this group.



Max. score	2	2	2	2	2	2	3	5	20	3	2	2	2	2	1	3	5	20
Initials	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	**Total**	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	**Total**
M.M.	2	0,5	2	2	2	0	3	1	12,5	0	0	2	1	2	0	3	5	13
B.Š.	1	0	2	2	2	0	3	4	14	3	0	2	2	2	0	3	2,5	14,5
B.P.	2	1	2	2	2	0	3	3	15	3	1	1	1	2	0	3	2,5	13,5
R.G.	0	0	2	1	2	0	1	0	6	3	1	2	2	0	0	3	2,5	13,5
P.W.	2	0,5	2	0	2	0	3	5	14,5	3	1	2	2	2	0	3	5	18
M.S.	2	0,5	3	0	2	0	3	0	10,5	3	0,5	2	2	2	0	3	0	12,5
N.M.	2	0	2	2	2	0	3	5	16	3	0	2	2	2	1	3	5	18
T.V.	1	1,5	2	1	2	0	3	5	15,5	3	0	2	1	2	1	3	5	17
P.Z.	2	1,5	2	2	2	0	3	5	17,5	3	2	2	2	2	0	3	5	19
S.Š.	2	0,5	2	0,5	2	0	3	5	15	2	1	2	2	2	1	3	5	18
I.Š.	2	0	2	2	2	0	3	5	16	3	0	2	2	2	0	3	5	17
E.B.	2	1	2	2	2	1	3	5	18	3	2	2	2	2	0	3	5	19
A.N.	1	1	2	2	2	0	3	5	16	3	2	2	2	2	0	3	5	19
T.M.	2	0,5	2	2	2	0	3	5	16,5	3	0	2	2	2	0	3	5	17
O.A.	2	0	2	2	2	0	3	4	15	3	0	2	2	2	0	3	5	17
D. Š.	0	1	2	0	2	0	3	3	11	3	0	2	2	2	0	3	5	17

Table 5.2 Comparison of Pre–Test and Post–Test Scores for Group 2

Comparative Findings 5.5 Although both groups demonstrated improvement after the intervention, Group 1 (Blue-Bot) exhibited a more substantial and consistent gain in algorithmic thinking skills than Group 2 (Robot Emil). The difference in progress suggests that embodied, tangible interaction with a physical robot provided more immediate feedback and fostered collaborative problem-solving strategies, which contributed to higher learning gains. By contrast, the abstract, screen–based tasks in Robot Emil posed difficulties for some pupils, particularly in transferring symbolic commands into expected results, which in some cases led to regression in scores.

Observational Insights 5.6 Qualitative observations supported the quantitative findings. Pupils in the Blue-Bot group actively discussed their ideas, used trial–and–error approaches to refine solutions, and developed strategies for debugging collaboratively. They were able to visualize the robot's movements and anticipate errors before execution, which enhanced their confidence and algorithmic reasoning. In contrast, pupils using Robot Emil often worked more individually, and some struggled with abstract command sequencing, requiring additional teacher support to plan and test solutions effectively.

Summary 5.7 The analysis indicates that both educational tools can foster algorithmic thinking; however, Blue-Bot provided stronger and more uniform learning gains among fourth-grade pupils in this study. The results highlight the potential benefits of introducing tangible, collaborative robotics activities at the early stages of algorithmic thinking development, followed by digital environments like Robot Emil for consolidation and further abstraction of programming skills.

Group 1, which worked with BlueBot, achieved a greater point difference. We assume that this is because the students tried not only to complete the tasks, but also to create their own. They also created correct and incorrect scripts for the given task for other groups of students to check and run. We ultimately consider these facts to be decisive and relate them to the results of both groups. Compared to only completing assigned tasks, creating tasks focuses the pupil's attention more on the anticipated result, develops anticipation of the future. Group 1 actually, had to look at the issue from multiple angles while solving the task, which in our opinion, enabled them to be more successful in the post–test by a greater point difference than Group 2.

6. Findings

Our action research provided several important insights into how primary school pupils interact with Blue-Bot and Robot Emil during algorithmic thinking activities, as well as into the pedagogical conditions that support or hinder their learning progress.

Organization of Work and Group Dynamics with BlueBot 6.1 Working in groups of six pupils with one Blue-Bot and one mat proved to be an effective organizational strategy under standard school conditions with limited material resources. The distribution of roles—two programmers, two recorders, and two testers—enabled active engagement of all participants and reduced the likelihood of disagreements, as every pupil had an opportunity to experience each role within a structured rotation system. This arrangement also fostered accountability and cooperation, as pupils learned to plan, document, execute, and debug tasks collaboratively.

The graded tasks, grouped into sets of three or six, ensured fairness and balance, giving each pupil at least one or two opportunities per role. This structure maintained pupils' motivation, supported peer learning, and allowed pupils to observe alternative approaches to problem–solving. Our findings suggest that role rotation, combined with clearly defined task sequences, is a key factor for smooth group work and successful implementation of tangible robotics in classrooms. When scaling this approach to larger or smaller groups, teachers should adjust the number of tasks and available roles to keep every student actively engaged.

Differences in Digital Skills and Learning with Robot Emil 6.2 While Robot Emil provides a structured, child-friendly environment for visual programming, its successful use depends strongly on pupils' prior experience with computers. In our sample, some pupils had already mastered essential skills such as operating a mouse, navigating menus, and saving files, whereas others lacked these foundations. Pupils with limited digital literacy were often distracted from the programming tasks themselves, as they had to focus on executing basic computer operations. This resulted in slower progress and occasional frustration, highlighting the need for preparatory sessions before engaging in algorithmic problem-solving activities on digital platforms.

We recommend that teachers plan at least one introductory, non-assessed session dedicated to familiarizing pupils with the Robot Emil interface. This session should focus on:

- learning to control the application and use graphical commands,
- understanding the symbols and interface functions,
- practising basic navigation skills (mouse clicks, file handling).
- Once pupils develop fluency with these basic interactions, they can fully focus on logical reasoning, sequencing, and debugging during subsequent lessons.

Collaboration and Classroom Climate 6.3 Group collaboration with Robot Emil was less structured compared to Blue-Bot activities, as pupils tended to work more individually on their computers. However, spontaneous cooperation occurred, particularly when pupils encountered difficulties or wanted to compare solutions. The quality of cooperation depended strongly on classroom atmosphere, pupils' prior experience with teamwork, and the teacher's ability to mediate conflicts or guide group discussions. Successful collaboration required patience, empathy, and deliberate scaffolding by the teacher to ensure that pupils supported each other rather than becoming distracted or competitive.

Overall Pedagogical Implications 6.4 Based on our observations, the following recommendations emerged:

For tangible robots (Blue-Bot): Structured role assignment and rotation enhance participation, fairness, and peer learning. Graded task design supports gradual skill development while keeping all pupils engaged. Providing clear instructions for each role further ensures that students understand their responsibilities and can contribute effectively. Teachers should also encourage reflection after each activity to consolidate learning and identify areas for improvement.

For visual programming (Robot Emil): Initial sessions should build ICT operational skills before introducing algorithmic challenges. Teachers should actively encourage peer discussion and cooperative problem-solving to mirror the collaborative benefits seen with tangible robots.

For both tools: Teachers should monitor group dynamics closely, provide empathetic support during conflicts, and adjust task complexity to ensure all pupils can experience success while being challenged to think critically. Ongoing assessment and feedback help tailor activities to individual needs, maximizing learning outcomes. Additionally, integrating cross-curricular connections strengthens the relevance of programming tasks and supports broader cognitive development.

These findings emphasize that effective use of educational robotics and programming tools in primary education relies not only on the quality of the activities themselves but also on careful orchestration of classroom organization, preparatory scaffolding, and supportive teacher facilitation. Ongoing assessment and feedback help tailor activities to individual needs, maximizing learning outcomes. Additionally, integrating cross-curricular connections strengthens the relevance of programming tasks and supports broader cognitive development.

Limitation 6.5 Presented study provides important insights into the development of algorithmic thinking through the use of BlueBot and Emil Robots with relatively small sample size, with two unequal Grade 4 pupils groups. The short–term intervention constrained the ability to assess long–term effects. Despite our effort to ensure comparable conditions across experimental groups, uncontrolled external variables, such as differences in teaching approaches, classroom dynamics, and student motivation may have influenced the outcomes. BlueBot and Robot Emil introduced varied cognitive demands and learning curves, potentially affecting pupils' performance. Although our action research proved higher progression while working with BlueBot, we do not consider this tool as more useful than Robot Emil due to few participants and short – term intervention. Both BlueBot and Robot Emil we consider to be highly effective tools to foster development of algorithmic thinking in early primary education.

7. Conclusion and Discussion

This study demonstrates that educational robotics, represented by BlueBot and Robot Emil, provides substantial benefits for developing algorithmic thinking, problem-solving skills, and collaborative learning in primary education. Both robots effectively engage pupils in hands-on programming, fostering computational competencies while enhancing motivation and self-confidence in approaching digital challenges.

BlueBot, with its tangible floor-based interface, supports intuitive understanding of sequencing, spatial orientation, and the relationship between commands and outcomes. Activities promote embodied cognition and teamwork, as pupils plan, test, and iteratively refine algorithms collaboratively, reinforcing debugging, pattern recognition, and communication skills [1].

Robot Emil, developed under Professor Ivan Kalaš, introduces more complex programming concepts through a structured, screen-based environment. Its progression from basic sequencing to cycles, abstraction, and optimization aligns with current informatics education requirements. Empirical data, including pre- and post-test assessments, indicate that algorithmic thinking improves across both robotic modalities, with BlueBot priming intuitive and collaborative skills, and Robot Emil fostering deeper abstraction, systematic problem decomposition, and iterative debugging [11].

The inclusivity of the "low floor, high ceiling" approach in both tools provides diverse activities and adaptable challenge levels, accommodating pupils with varying skills and supporting differentiated instruction, allowing all students to succeed. This approach aligns with pedagogical best practices and current curriculum reforms emphasizing inclusion, computational literacy, and higher-order thinking [6],[10]. Teachers emphasized that clearly defined learning goals, structured reflection, and ongoing support are crucial for maximizing educational outcomes. Integrating robotics into interdisciplinary contexts, including mathematics, science, and real-life problem-solving, enhances durable and transferable skills. However, challenges such as differences in teachers’ prior experience can affect pupil engagement; therefore, sustained professional development and access to culturally and linguistically appropriate resources, as provided with Robot Emil, are essential for long-term implementation.

In conclusion, both BlueBot and Robot Emil serve as catalysts for cultivating algorithmic and computational thinking in primary school settings. Their deployment in the classroom not only addresses urgent educational objectives but also inspires creativity, confidence, and collaboration among young learners. Future research should explore longitudinal effects of sustained robotics integration, the impact of teacher–led versus peer–led learning models, and the potential for robotics to bridge gaps in digital equity across regions and school systems.

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