Utilizing Robotics in Maths in Primary Education: A Case Study

A. Goltsiou, C. Sofianopoulou
Harokopio University/Department of Informatics and Telematics, Athens, Greece
aikgoltsiou@gmail.com, csofian@hua.gr

***Abstract* - The use of robotics and programming help to approach mathematical concepts in an alternative way through differentiated learning. The approach contributes to the cultivation of mathematical thinking through experimentation and code correction, through visualization, as well as the inclusion of students. The aim of the paper is to present how robotics and specifically the Lego Education Spike Essential were integrated into the teaching of Geometry in the 1st Grade of a Greek primary school. The activities were included in three teaching scenarios in the framework of the utilization of the new Greek curriculum. The evaluation of the action was done by investigating the opinions and attitudes of the students and with structured observation by the teacher. The students' formative and final assessment were integrated into Moodle. Also, the programming of students' constructions formed the final evaluation of the implementation. From the evaluation of the action, it emerged that the students understood mathematical concepts, they cultivated collaborative, digital and programming skills in a pleasant collaborative learning environment. It is proposed to utilize robotics from an early age in the teaching of mathematics in the new Greek curricula, as a means of cultivating students' mathematical thinking.**

Keywords - robotics; Lego Education Spike; mathematics; differentiated learning; Moodle

I. INTRODUCTION

The new Greek school curricula are oriented towards learning outcomes through a combination of experiential learning and digital educational tools [1]. The approach is two-fold and achieves the differentiation of learning material and implementation, in accordance with what differentiated pedagogy stands for. There are many individual differences between students, which increase as students progress from one level of education to another [2]. Accepting diversity and moving towards an inclusive school is an international orientation [3]. Gardner [4] with the theory of multiple intelligences supports the different ways of perceiving and understanding the concepts of everyday life by each person individually. Through differentiated pedagogy, a flexible framework is formed, which allows each student to follow his own way of learning in a collaborative learning environment. [5].

Cultivating students' critical thinking is achieved by making them active and engaging with constructions that are meaningful to them. Since the 1990s it has been argued that those students who are involved in programming, who write code are able to understand concepts through the process of experimenting with their ideas. Being able to correct errors in the code fosters critical and mathematical thinking [6].

By utilizing ICT in teaching practice, students' critical thinking is cultivated, through visualization, investigation and the immediate feedback they receive. The participation of each student is immediately visible and motivates the members of the group in cooperative teaching and learning, where teaching can be implemented with blended learning [7].

A. The use of robotics at school-Playing with robots

There are many digital applications used in education. Moodle is a modular learning environment (https://moodle.com/) with module configuration that makes it flexible. It has mainly been used in adult education. In recent years, it has also been utilized by Secondary and Primary Education, contributing to the cultivation of cognitive skills, communication, collaboration, and digital literacy [8, 9, 10]. Among the Moodle resources there are now the interactive .H5P files. The activation of students in teaching is particularly achieved by the use of .H5P files [11, 12] which contribute to the improvement of their performance.

The colored cards of Cody and Roby, created by Prof. Bogliol [13] were exploited in Italy along with other forms of programming learning activities, without the use of computers and tablets. These are unplugged activities. From the action of cultivating digital literacy, it was seen that learning became more interesting and effective, as the students were active in everyday issues. In addition, they improved metacognitive skills as they trying to find a solution. L. Klopfenstein et al. [14] used Cody and Roby cards in an augmented reality game and they emphasized the exciting atmosphere created by the action. Fabrizio Ferrari et al. [15] used Cody and Roby as a pre-organizer to introduce students to coding with Scratch. The game contributed to the development of programming skills and as a cognitive scaffold learning Scratch.

With game-centered learning [10] Vygotsky argues that a greater participation of students is achieved. The Lego Education Spike Essential kit has distance and call sensors. It is programmed by students using either its own block language or the Scratch programming language. Through its use, exploratory learning and understanding of cause and effect is promoted (https://education.lego.com/en-us).

Pinto-Llorente [16] used the Lego Education WeDo 2.0 robotics kits and documented that contributed to the cultivation of children's computational thinking. In addition, engaging with the kits contributed to the activation of the students in primary education, as they had the opportunity to learn how to build 3D models and program them. Veselovská et al. [17] utilized the robotics equipment, Lego Education WeDo 2.0, in 3rd and 4th grade students of Primary Education, who mainly focused on the construction of robotic models, with the aim of integrating robotics into the school curriculum and comparing it with the results of countries with different cultural environments. Wu et al. [18] in their comparative research on Lego Education WeDo 2.0 students from 1st to 4th grade in Taiwan and Slovakia, they concluded that educational robotics contributes to the cultivation of communication, cooperation and engineering skills in students, activating them through inquiry learning.

Petrovič [19] utilized the Lego Education Spike Prime robotics kit in the subject of Physics and suggests extending the use of robotics to other subjects in the curriculum and to mathematics. His suggestions concern the implementation of activities in Physics and mathematics.

Nikolos [20] proposed the use of the Scratch 3.0 language to program the Lego Education WeDo 2.0 robotics kit, for the implementation of a Primary Education teaching scenario. Lego Education WeDo 2.0 kits are leveraged in STEM Methodology as Lytra & Drigas said in systematic review [21].

The aim of this article is to present how robotics and specifically Lego Education Spike Essential were integrated in the teaching of geometry at the 1st Grade of a primary education Greek school. The question is:

Although how can robotics be integrated into the teaching of geometry at the 1st Grade in Primary Education.

II. METHODOLOGY

To investigate the question, a project was designed and implemented in the teaching of geometry during the school year 2022-23. The implementation was done in 15 students, 7 boys and 8 girls, aged 6 years, at the 1st grade class of a Greek primary school. A total of eight (8) teaching hours, two (2) mathematics hours of the program timetable were used for each activity. The activities were part of three teaching scenarios, as extension activities in the daily life of the students. The heterogeneity of the class from a socio-cultural point of view as well as the different learning profiles of the students were taken into account [4] in the context of differentiated teaching [5]. The activities were structured forming a cognitive scaffold for the next activity. At the end of each activity, a formative assessment was done in Moodle, as a differentiation of the students' evaluation method [5]. The action was completed over a two-week period.

Students have had experience in collaborative experiential learning and blended learning in Moodle since the beginning of the school year. They had used the robotics kit, Cody and Roby cards from previous STEM activities with their class teacher. They also knew how to use the Lego Education Spike app on tablets. Students participated in the Lego programming activities in groups and in the plenary in the classroom that means to be attended by all students in the class. Specifically, students collaborated in groups of 5 people, where two students programmed on the tablets taking turns with the others. The rest of the students in the group were assistants and evaluated the programming scenario during its construction. That means that in each activity two students were programmers and the other evaluators. The unplugged activity was implemented in plenary.

During the action they were implemented:

A. Unplugged activity with Cody and Roby cards.

B. Robot programming in straight line, square and rectangle path.

C. Evaluation

- Structured observation by the teacher.
- Student self-assessment in Moodle.
- Investigating students' opinions and attitudes after implementation.

The interactive content (.H5P) files and the quizzes of the Moodle environment were used for the formative assessment. The initial and final evaluation of the action was done with structured observation by the teacher based on the objectives of the activities, investigation with questionnaires of students' opinions and attitudes about the Moodle digital environment and engagement with robotics in mathematics, the activation of the students in the group, the programming scenarios and the constructions completed by the students.

A. *Action flow - implementationοή*

The subject of the action was the consolidation of concepts of geometry with an alternative approach in the context of differentiated learning and with the cultivation of digital skills and programming. Each activity was a cognitive scaffolding for the next one, both at the level of geometry and at the level of programming. After teaching each concept in geometry, the students recalled the characteristic elements of the shapes and programmed the movement of each object with blocks in the application of the tablets to form a line, square or rectangle. The activities:

- 1η Programming robots with straight line motion.
- 2η Unplugged activity with Cody and Roby cards following a specific path.
- 3η Programming robot that moves in a square-shape.
- 4η Programming a robot that moves in a rectangle shape.

The students were engaged in the construction of the robot-car taking turns per group. They chose the construction they would make from the Lego Education Spike library in plenary. The building instructions were projected onto the classroom and groups constructed part of the car while the other groups programmed the construction. So all the groups built and programmed the

same object. When construction was complete, they tested their programming script, improved it and experimented with adding picture and music commands. The Unplugged activity with Cody Roby cards was used to facilitate the students' transition from the hands-on material of the cards to the more abstract of the screen and way of checking the correctness of the commands.

III. WHAT WE HAVE FROM THE IMPLEMENTATION

The students gradually presented the results of the constructions and programming they did to the plenary (Fig. 1) in each activity.

Figure 1. Constructions with Lego Education Spike Essential

The check of the movement of the object was done first in the group and then in a mockup of a route in the city, which built by themselves (Fig. 2). Thus, they connected their construction with everyday life [5], so that they could better understand why they learn to draw shapes.

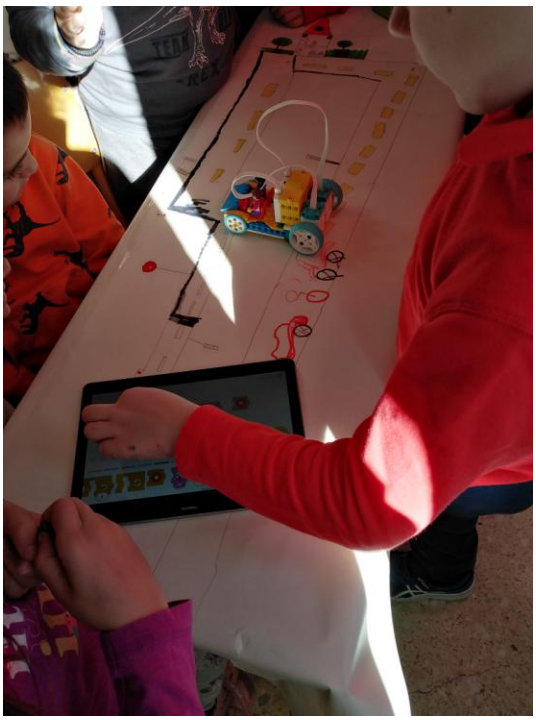

Figure 2. Giving directions

A. *Unplugged activity with Cody and Roby cards*

With the activity Cody and Roby (Fig. 3) a connection of programming with manual material was made. The activity was implemented in plenary by applying peer review.

Figure 3. Giving directions via Cody and Roby cards.

B. *Robot programming in straight line, square and rectangle path*

The unplugged activity served as a scaffold for moving into more complex programming in the Lego Education Spike. The groups created their own script to program the robot that moves in a line, in square-shape and in a rectangle shape (Fig. 4). In fact, they realized that the program would remain the same if they changed the number of steps under each movement command, instead of placing one movement command next to the other. They presented, commented on other groups' scripts, got ideas for their own script and added audio and visual commands.

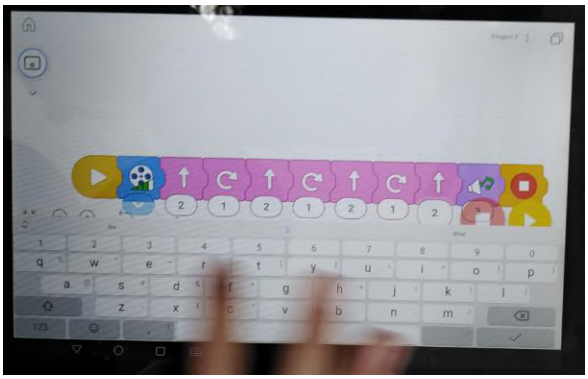

Figure 4. Programming a square

The students perceived the programming of the rectangle as a pattern (Fig. 5), by recalling previous knowledge and using it in a completely different environment.

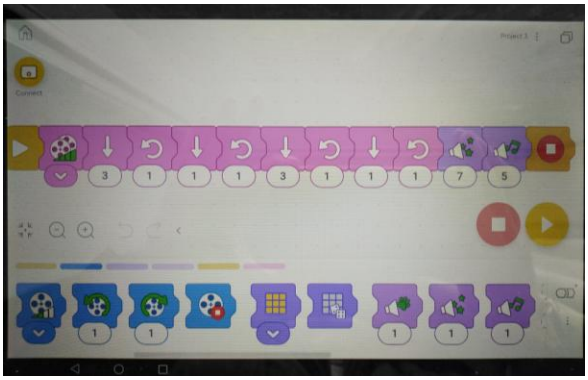

Figure 5. Programming a rectangle

C. Evaluation

The evaluation was about the integration of robotics into the teaching of mathematics. It was conducted with an initial and final questionnaire of the students with structured observation by the teacher based on cognitive goals and cultivating programming skills.

The evaluation of the action was done in combination, through the results of the students' tasks, the quiz, the students' formative assessment tasks and using a questionnaire. The students' opinions, their attitude towards using robotics in the future in the mathematics, the difficulties they had faced and how they were solved, the communication and cooperation in the group were recorded.

From the teacher's initial observation, it emerged that the students had little programming experience with the Lego Education Spike, as they had used the kit with him in a previous STEM activity. The students knew how to program the robot in a straight line. They had cultivated their digital skills due to utilizing the digital classroom since the beginning of the school year. In addition, they knew how to work together experientially. The final rubric observation of the teacher showed that five (5) students of the fifteen (15) students (33.3%) did not identify the error in the programming scenario with the figures. The 46.6% did not know how to correct the error that means seven (7) of fifteen (15) students.

The final evaluation quiz for programming included three (3) questions with pictures, of the matching, multiple choice, true-false type. The matching question had images from the three programs that students had created that was the line, the square and the rectangle. The students had to match the programs with the words straight line, square, rectangle. In the multiple choice questions students had to choose from the arrows what the command meant. In the true-false question students had to decide whether the toy car reached the end of the route or not at the image with Cody and Roby cards. The results showed that 73.3% answered correctly to all the questions.

With an electronic questionnaire, students' opinions and attitudes about robotics mathematics activities and the use of the Moodle environment were investigated. The cooperative activity of the students during the implementation, the completion of the tasks and the interactive content of Moodle constituted the formative assessment. The final evaluation consisted of the students' assignments that were implemented experientially and the final quiz in the digital classroom.

The final investigation of students' opinions and attitudes towards the integration of robotics into the subject of mathematics was recorded in an anonymous electronic questionnaire with dichotomous questions and completed by 14 students. The results are presented in Table 1. Table 1 presents frequency.

TABLE I. POST- QUESTIONNAIR: STUDENTS' OPINIONS

	Students' opinions		
	Questions	***Yes***	***No***
1	I like doing math at school with robotics.	100%	0%
2	I understand geometric shapes better by doing robotics.	100%	0%
3	I see my programming mistakes.	92.9%	7.1%
4	I am correcting my programming mistakes.	85.7%	14.3%
5	I want to continue doing robotics in mathematics.	100%	0%

The final questionnaire highlighted the desire of all the students to continue the involvement with robotics in mathematics. The inability of some students to solve the problem did not deter them from wanting to do math with robotics in the future.

As far as their digital classroom is concerned, 77% of the students say that Moodle is easy to use, helps them learn, they like working on Moodle and want to continue using it.

IV. CONCLUSION

This paper shows how the Lego Education Spike Robotics Kit was used in 1st Grade in primary education to help students learn the shapes square and rectangle better.

The question is how the Lego Education Spike Robotics Kit could be leveraged to help students learn better geometric concepts through programming and cultivate programming skills. During the implementation the teacher observed and recorded the existence of a cooperative climate among the students, a pleasant atmosphere was created and the students learnt geometric concepts with the help of programmable materials. From the questionnaire of students' opinions and attitudes about the involvement with robotics, the students' positive attitude towards the activity emerged. It was observed that students gained programming knowledge through robotics, cultivated critical thinking and problem solving, cultivated 21st century learning skills.

From the teacher's observation rubrics, the investigation of the students' opinions, it emerged that it is possible to utilize robotics in dealing with geometry concepts in primary education. The robotics kit functioned as both a haptic device and a digital tool through its tablet application. The unplugged activity was helpful in understanding application commands. Students benefited, were energized and their creativity and positive attitude towards mathematics was enhanced.

The work supports the studies concerning the use of robotics in mathematical problems and the cultivation of mathematical thinking [13, 14, 15, 16, 17, 18, 19]. It enhances learning through a pleasant atmosphere of collaboration [16, 17, 18, 19, 20] and differentiated [3, 4, 5].

It is proposed to use robotics from an early age, in the teaching of mathematics in the New Greek curriculum, as a means of cultivating students' mathematical thinking. In addition, engaging where possible in the subjects of the rest of the curriculum, as this enhances creativity and mathematical thinking.

V. LIMITATIONS

A Lego Education Spike Essential robotics kit was used to implement the activities in a class of 15 students. It would have been easier to implement if each students group had its own robotics kit. The question arises whether it would be feasible to implement following the same methodology in a more populous class. In addition, it is deemed necessary to train the teachers of each school, in the context of in-school training, with the implementation of laboratory training.

REFERENCES

[1] IEP (2021). http://iep.edu.gr/el/nea-programmata-spoudon-arxiki-selida.

[2] D. Reschley, Learning characteristics of mildly handicapped students:Implications for classification, placement and programming. In: M. Wang, M. Reynolds & H. Walberg (eds). *Handbook of special education. Research and practice. Volume 1: Learner characteristics and adaptive education.*. Pergamon Press, pp. *35-5,*1987.

[3] UNESCO, The Salamanca statement and framework for action on special needs education. Paris: UNESCO, 1994.

[4] H. Gardner, Frames of mind: The Theory of multiple intelligences. New York: Basic Books, 1983.

[5] C. A.,Tomlinson, Grading and Differentiation: Paradox or Good Practice?, *Theory Into Practice, 44:3, 262-269,* 2005

[6] S. Papert, Mindstorms: *Children, Computers, And Powerful Idea,* Basic Books, 1990.

[7] R. Al-Maroof, N. Al-Qaysi, S. A., Salloum & M. Al-Emran, Blended learning acceptance: A systematic review of information systems models. Technology, Knowledge and Learning, 1-36 (2021).

[8] K. Brandl, ARE YOU READY TO "MOODLE"?. *Language Learning & Technology,*19(2), 16-23, 2005.

[9] D. Pérez-Marín, R. Hijón-Neira, A. Bacelo & C. Pizarro, Can computational thinking be improved by using a methodology based on metaphors and scratch to teach computer programming to children? Computers in Human Behavior, 105, 2020.

[10] L. S. Vygotsky, Play and its role in the mental development of the child. Soviet psychology, 5(3), 6-18, 1967.

[11] A. J. Unsworth & M. G Posner, Case Study: Using H5P to design and deliver interactive laboratory practicals. Essays in Biochemistry, 66(1), 19-27, 2022.

[12] R. Singleton & A. Charlton, Creating H5P content for active learning. *Pacific Journal of Technology Enhanced Learning*, *2*(1), 13-14, 2020.

[13] S. Altieri, Recent history of coding in Italy. In *EDULEARN21 Proceedings* (pp. 42-49). IATED, 2021.

[14] L. Klopfenstein, A. Fedosyevev & A. Bogliolo, Bringing an unplugged coding card game to augmented reality. In *INTED2017 Proceedings* (pp. 9800-9805). IATED, 2017.

[15] F. Ferrari, A. Rabbone & S. Ruggiero, Experiences of the T4T group in primary schools. In *The Proceedings of International Conference on Informatics in Schools: Situation, Evolution and Perspectives* (p. 130), 2015.

[16] A. M. Pinto-Llorente, Developing Computational Thinking Using Lego Education WeDo at 4th Grade of Primary Education: A Case Study. In *Research Anthology on Computational Thinking, Programming, and Robotics in the Classroom* (pp. 156-174). IGI Global, 2022.

[17] M. Veselovská, Z. Kubincová, K. Mayerová, Comparison of LEGO WeDo 2.0 Robotic Models in Two Different Grades of Elementary School. In: Merdan, M., Lepuschitz, W., Koppensteiner, G., Balogh, R., Obdržálek, D. (eds*) Robotics in Education. RiE* 2019. Advances in Intelligent Systems and Computing, vol 1023. Springer, Cham, 2020.

[18] P.-J. Wu, F. -Y. Chiu,, K. Mayerová and Z. Kubincová, Educational Robotics at Primary School: Comparison of Two Research Studies, *17th International Conference on Information Technology Based Higher Education and Training (ITHET),* pp. 1-5, 2018.

[19] P. Petrovič, Spike up prime interest in physics. In *Robotics in Education: Methodologies and Technologies* (pp. 146-160). Springer International Publishing, 2021.

[20] Δ. Νικολός, Εισαγωγή στον προγραμματισμό του Lego WeDo 2.0 με το Scratch 3.0. Διεύθυνση Επιμόρφωσης & Πιστοποίησης: *Εκπαιδευτικά Σενάρια από το Υλικό της Εκπαίδευσης Επιμορφωτών Β' επιπέδου ΤΠΕ*, 2018.

[21] N. Lytra & A. Drigas, STEAM education-metacognition–Specific Learning Disabilities. *Scientific Electronic Archives, 14*(10), 2021 .