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Learning with Educational Robotics through Co-Creative Methodologies

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Abstract. STEM education is crucial in successfully shaping future technology driven societies. It is important to engage learners from an early age with STEM in order to facilitate successful entry into relevant careers. Towards that, educational robotics are a proven, effective introduction to overall STEM concepts but also to hands-on skills. Co-creation, a marketing method, tailor made to foster participation and engagement, translated successfully in educational contexts. In this work we present a co-creative robotics curriculum for primary school education and its impact on young learners' perceptions for STEM careers. Learners co-created educational robotics activities to learn from them. A validated questionnaire for assessing the learners' perceptions for STEM careers was administered before and after the curriculum. All learners improved their perceptions for STEM careers after the co-creative robotics curriculum. This study initiates a greater endeavor for exploring the impact of co-creative robotics in learning efficacy and STEM careers engagement.

Keywords: Lego® Mindstorms® EV3, STEM education, Programming, Co-creation, problem based learning, STEM careers, Primary Education

1 Introduction

STEM education is considered crucial factor in fueling the current and future workforce 1. The endeavor of supporting students in conceiving heavily the gist of STEM disciplines are strengthened by the integration of technology 2 as technology has brought substantial changes in all aspects of our lives, education included. In the past, the focus was on how to render students adept users of devices and applications. Nowadays, much of the debate is about how students can become skilled designers and creators of digital artifacts and technology-rich environments not only have positive effects on students' achievement in all areas 3, but also create new ways for developing students' social interaction skills and for encouraging problem-solving skills, creativity, social and cognitive development 4. STEM education can enhance skills that facilitate exponential growth of digital technologies in recent years 5 and helps students that are now required to develop new competencies, to effectively engage in our digital world 6. One promising approach to increase STEM attitudes, knowledge, skills and workforce capacity is the use of robotics 7. Computer technologies such as robotics can be used as "mind tools" which involve students in using modern technologies to solve problems 8. Through hands-on experimentation, such technologies can help youth to translate abstract mathematics and science concepts into concrete real-world applications 7. Moreover, educational robotics (ER) have become popular in teaching Science, Technology, Engineering, and Mathematics (STEM) because ER activities enable real-world applications of engineering and technology and help students to understand the abstract nature of science and mathematics subjects 9.

1.1 STEM Problem-Based Learning

Problem Based Learning (PBL) is a learning method through which the learners gain and develop upper level skills such as problem solving and critical thinking, while eliciting information from personal real life experiences and acquiring determinate knowledge about their own learning 10. PBL is focused on experiential learning organized around the investigation, explanation, and resolution of meaningful problems 11. Collaborative problem-solving groups are a key feature of PBL. Engagement and problem-based instructional approach are widely accepted and used in physics education throughout the world 12.

STEM PBL is based on the same theoretical background with PBL and the interdisciplinary feature combining science, technology, engineering, and mathematics is added 13. In STEM PBL classrooms, students are required to solve problems and engage in ill-defined tasks within the boundary of a well-defined outcome collaborating with other group members 13, while effective STEM PBL should be interdisciplinary and contain diverse content objectives within the context of hands on activities to produce an artifact 14. STEM PBL classrooms are more student-centered, where the teacher is expected to play a role as a guide and requires a professional teaching force empowered with the skills necessary for designing learning experiences that maximize student potential 15. Students who have experienced STEM PBL showed positive attitudes toward learning itself, team communication, and collaborative behavior 16, 17. Furthermore, STEM PBL was examined with respect to increasing students' interest, self-confidence, and self-efficacy 18, which was highly related to the components of STEM BPL such as collaborations in group work and contextual problems reflecting students' real world experiences 13.

1.2 Science Teaching and Inquiry

Scientific inquiry is considered the centerpiece of science teaching 19. It is an effective mode of learning to improve students' content knowledge 20, advance their scientific process skills 21, 22, nurture their attitudes toward school science 20 stimulate their motivation to learn science, foster their understanding of the nature of science 23 and communication skills 21. Students should be able to propose questions, investigate problems, present a hypothesis based on the observed patterns, identify different solutions and answers, and select the best answer and solution (initiating and planning skills). Finally, students should be able to work as a team and should have the opportunity to communicate their thoughts, results, and procedures with their team-mates during science classes (communication and teamwork skills) 24.

Robotics activities are ideal for teaching scientific inquiry skills. In inquiry-based learning, students need a rich context to investigate questions and develop scientific argumentation skills 25. This context is usually not available in the traditional classroom and thus Robotics activities may be a promising alternative, as they may provide a rich context needed for students to identify and investigate problems, generate hypotheses, gather and analyze data, and to determine findings and interpret results 19.

1.3 Robotics Education: Pedagogical Theories and Learning Approaches

During the last few years, robotics is being introduced in school education, from kindergarten to higher secondary school, either as an interdisciplinary learning activity or focused on school subjects such as science, maths, informatics, and technology 26. Studies in the field of robotics have reported that robotics have a potential impact on students' learning in different subject areas (Physics, Mathematics, Engineering, Informatics and more) and on personal development including cognitive, meta-cognitive and social skills, such as: research skills, creative thinking, decision making, problem solving, communication and team working skills, all of them being essential skills necessary in the workplace of the 21st century 27. In robotics, problems are open-ended, permitting many solutions and many approaches, while it affords opportunities for learning problem-solving techniques and processes, integrates a number of domains, exposes realistic constraints and issues, and leaves room for creativity 28. As students program a robot to complete a task, they are putting themselves into a situation where the robot is acting. Students are trying to "think" like a robot and reflecting on their thoughts on how a task should be completed 29. The main theories behind educational robotics are constructivism and constructionism 26. Papert believed that knowledge construction happens most effectively in a context where the earner is consciously engaged in constructing a public entity, whether it is a sand castle on the beach or a technological artifact 30. Constructivism/constructionism methodologies require the transition to the design of transparent ("white-box") robots where users can construct and deconstruct objects, can program robots from scratch and have a deep structural access to the artefacts themselves rather than just consume ready-made technological products 31.

29 conducted a literature review in order to examine the methods and platforms of robotics that have been used in science education. All the approaches below follow the ideas of constructionism introduced by Papert and constructivism derived from Piaget's work 30. Their research accented that the approaches applied in the educational robotics context are:

- Discovery learning
- Collaborative learning
- Problem solving
- Project-based learning
- Competition-based learning
- Compulsory learning

Collaborative learning and Problem solving are two approaches that are adopted and applied in this study. Collaborative learning could be organized in combination with any other approach used in educational robotics if students are allowed to communicate during the learning process 29. Problem-solving and higher-order thinking skills can be developed through computer programming, a pedagogical practice in the classroom that promotes learning and creating 32. Computer programming requires students to engage in problem-solving process that forms the defining core of computational thinking 33. This process comprises of a number of phases including: framing problems in a manner that enables them to be solved using computational tools; organizing and analyzing data; using models and simulations to represent data; implementing algorithmic thinking to automate solutions; evaluating solutions; and implementing the problem-solving process to other contexts 33. In addition to domain-specific skills, children who build a strong foundation in computational thinking competencies can become more effective problem solvers and critical thinkers 34 while at the same time students develop their analytical and synthetic thinking, foster their skills in designing and solving algorithms, and affects in a positive way their creativity and imagination 35.

1.4 Co-Creation in Educational Robotics with Students

Robotics programs have been proven to be successful tools to engage students of K-12 in STEM and create interest in careers in the STEM field 36, 37 while they have also been recognized as a topic that easily excites college level engineering students, offers hands-on experience to support theoretical concepts, and fosters multidisciplinary work 38. They also enable real-world applications of the concepts of engineering and technology and help to remove the abstractness of science and mathematics 7. Robotics as an active, problem-based, team-centered approach to learning, relates well to current thinking in engineering and computing education 39 and problem-based learning is viewed as integrative and enhancing team-working skills 40. There is a rapidly developing interest in student generation of content, while it has been advocated as a means of fostering deep learning and high levels of students' engagement, leading to enhanced conceptual understanding 41. Some defining characteristics of student engagement include: challenging problem-based learning, collaborative learning, student–faculty interaction, and learning opportunities outside as well as inside the classroom 42. An ally in the promotion of students' engagement could be co-creation. Co-creation provides the meaningful context mandated by constructivism 43, where in this context, learning takes place through knowledge discovery and interaction during the process of co-creation of a concept, design or product 44. Indeed during the past decades there has been an increased interest in the numerous benefits of engaging students as partners, co-inquirers, who produce and co-create their own learning experience 45.

There is a significant body of literature that supports co-creative activities of students in educational robotics. A significant project involving children in a series of co-creation activities with robotics was performed by Druin and her team 46. Obaid and colleagues have worked specifically on the involvement of children with and without robotic knowledge in the early phases of a robot design process 47.In their study, they tasked small groups of either children or interaction design students with designing robots and activities. Based on their findings they designed a toolbox (Robo2Box) 48 that included the most common design elements found in both the drawings and the focus group discussions (from both children and interaction designers). Additionally, Arnold, Yip, and Kung 49 performed and described one co-design session with children to develop a friend robot. However, similar to the work by Obaid et al. 50, their intention was not to design an actual robot for the children, but instead to understand what kind of design input children could give.

All the above research indicates the rightful and essential application of co-creative and collaborative approaches amongst children when involving them in robotics activities. A collaborative approach invites co-creation, where through a transformation process individual's partner to attain a mutual outcome, engender diverse perspectives, practise participatory learning, synergy, and viable solutions that may not occur individually 51. These goals and directions, inspired research in our project to adopt co-design and co-creation methods for educational robotics in primary education. Through co-creation students will be given the chance to take authentic responsibility for the educational process, shift from being passive recipients or consumers to being active agents; at the same time, they could shift from merely completing learning tasks to developing a meta-cognitive awareness about what is being learned 52.

1.5 Computer Supported Collaborative Learning

As students have unique views about teaching and learning, they need to be invited to share their views on the education processes and to actively participate in the training process, to achieve improved results in learning, developing thinking skills and creativity, obtain rich understanding of concepts, and create knowledge and new educational processes 44. Therefore, creating collaborative and positive learning environments is essential to support students' opportunities to learn. This approach is strengthened through the selection of worthwhile intellectual tasks to support group work, communication, multiple abilities, and learning styles 53, 54 as well as and talk-based participatory discussions 55. One dimension of collaborative learning is the Computer Supported Collaborative Learning (CSCL). CSCL has constituted a dominant presence in online education, due to its great potential to articulate learning processes based on knowledge co-construction, and, consequently, it has become a research trend 46. The inclusion of Robotics to face-to-face CSCL adds a new dimension to this learning environment, while maintaining the face-to-face interactions, collaboration, and the underlying technological assistance, Robotics provides a way to insert real world capabilities to this learning setting 56.

2 Methods

2.1 Aim and Scope of this Work

The primary focus of this paper is to describe the methodology and outcomes of implementing co-creative robotics activities in the classroom of primary education. Specifically, it reports on the progression through open-ended robotics challenges of primary school learners, who co-created, with their teacher, programming solutions, through EV3 graphical programming environment. In these activities, they were exposed to new aspects of programming language and became versed in computational thinking, while co-creating with their teacher led to more engagement, creative thinking and successful learning results.

Additionally, a focus of this work was to explore this co-creative experience's impact on students' perception regarding STEM content and careers. Specifically, the research question explored was:

- Does the implementation of co-creation oriented robotics curriculum in elementary grades invoke changes in students' interest in science and careers in science?

2.2 Participants and Context

The study involved 20 students of the 6th Grade aged 12 years old and male (n=10) and female students (n=10) were equally represented in the sample and also a teacher who had the role of the coordinator and facilitator of the educational process. All, the participants attended the Robotics club "EV3 Junior Academy" which for the first time and for the school year 2018-2019 was conducted at the Experimental Primary School of the University of Thessaloniki in the city of Thessaloniki, in northern

Greece. The club started in November and ended by May and participants attended the club in their classroom once per week. The aim of the "EV3 Junior Academy" was to bring the possibilities of engineering to life for primary students and inspire them to solve challenging problems.

2.3 Technologies and Materials for Co-Creative Activities.

The activities were all based around the Lego® Mindstorms® Education EV3 core set and EV3 software environment. Students that enrolled in this club had to solve problems like engineers, try different ideas, and learn from mistakes and try again (design process). As the students and the teacher who offered the Robotics club at the school were the first users of this new type of club and learning activity, their role as designers and developers of the environment and the pedagogy was significant.

The "EV3 Junior Academy" Integration of technology into classroom instruction was particularly emphasized. There were:

a) a SMART Board connected to the teacher's computer and a digital projector in order to show the computer image. Students and teacher could control computer applications directly from the SMART Board display.
b) One Lego® Mindstorms® EV3 core set for Education (robot kit) per group of 2 students.
c) Lego® Mindstorms® Education EV3 app, free online
d) Students of EV3 Junior Academy were encouraged to "bring their own device" (iPad loaded with EV3 app) to use in the class for educational purposes as school couldn't provide them.
e) Masking tape, tape measure and stopwatches for each group.

2.4 Instrumentation and Measures

A pre-test/post-test as used to measure any possible change in students' interest towards science and science careers. The instrument used for the study was a 29-item, paper-and-pencil questionnaire, designed to assess perceptions of scientific disciplines and careers. It covered 5 variables (Science, Math, Engineering, Technology and Careers in them). Specifically, a 7 point Likert scale survey questionnaire "Assessing Interest in STEM Content and Careers" 57, where was administered to assess students' interest before the club started, and after the school club activities were completed. For each variable there was an adjective pair that gave the options from 1 to 7, with 1 being the most positive and 7 being the most negative aspect of the adjective (for details please see the Appendix).

The instrument was short, easy to use, and specifically targeted interests and attitudes in science and STEM. The language is appropriate for elementary through high school aged students and measured changes in interest and attitude. Once the survey was completed, a dependent (paired) samples t-test was conducted to see if the participants' interest significantly changed from before the club started (the pre-test) to after the club finished (the post-test).

3 Results

3.1 Co-Creative Game-Making Outcomes.

In this study, 5 case studies are presented, exploring students' engineering and co-creation activities with the Lego® Mindstorms® EV3 Robotics.

All 20 students participated equally in the 5 case studies with educational robotics.

Table 1. Activities undertaken as part of the co-design approach

Case	Learning Objectives	Duration	Co-creation Activities
Case 1	Decimal, fractional numbers, diameter, circumference, relationship between distance, speed and power level.	4 meetings	Co-create various SpaceRover configurations, learn as a team and collaboratively test how to use the EV3 programming language. Co-create various coding solutions to move the robot according to their worksheet.
Case 2	decimal numbers, fractions, relationship between friction, velocity and distance, graphing-averaging data.	3 meetings	Students collaborate in order to build the robot, co-create code to program it to complete the given challenge. Co-creative implement their ideas in the actual robot in order to collect data.
Case 3	Shapes, number of sides, internal angle and external angle.	3 meetings	Students build on their own knowledge while they collaborate and co-create code to make the robot draw shapes of various configurations.
Case 4	Basic arithmetic calculations, multiplication, measure of angles, how gyro, touch, ultrasonic sensors work, how to program EV3 robot with gyro, ultrasonic, touch sensors and understand the human body's sensory system.	4 meetings	Students work as a team in order to co-create the robot, use the inbuilt sensors. Co-create code to program the robot's movement using visual blocks and figure out how to solve efficiently real-world problems.
Case 5	How colour sensor works, how robot receive input from sensors, transmit signals and how to program EV3 robot with the colour sensor to make decisions and understand the human eye work.	2 meetings	Students work as a team in order to co-create the robot and use the inbuilt colour sensor. Co-create code to control robot's movement using visual blocks.

Students were encouraged by the facilitator to be active and adopt essential assertive roles during the educational process, while the facilitator also tried, discreetly, to provide students with help and guidance, when it was needed. Initially, students had to download on their iPads the official programming app from Lego® Education. There are six Robot Educator tutorials providing an effective guide to programming and hardware. Teacher also provided students with step-by-step instructions for how to use LabVIEW graphical programming environment and EV3 smart brick. During this introduction, students were able to: a) listen and actively participate by programming in LabVIEW and b) solve open-ended designed challenges that were provided by Lego® programming app. The graphical programming language facilitated the faster transition to more complex concepts by the end of the year 2018. All hands-on challenges followed a similar structure and were based around constructivist learning ideals of project-based learning and the emerging concept of co-creation. The learning objectives of all activities were a) to increase students' critical thinking skills, collaboration, communication and co-creation skills as well as the ability to design a solution to a challenge and b) to apply basic math functions, geometry and physics. Worksheets were given to each working group on a range of different space activities and open-ended challenges. There was no single right answer and the difficulty was progressively increasing. Brainstorming was conducted with the scenario and objectives in mind in order to exchange thoughts and ideas, which may lead to a joint, possible solution. At that stage all students were continually challenging their own knowledge and the knowledge of their peers and were encouraged to come up with several ways of solving the problem. Before moving to the "build" step, teacher made sure that each group had settled on a specific idea to implement without giving too much direction that may discourage them from thinking themselves and discover answers. All activities were based around a single robot, the "SpaceRover", which was used in all activities. Easy building instructions for this particular robot model were given to students on the first day of Robotics club and students used the materials provided in the core set to build the "SpaceRover".

Case 1

Our new "SpaceRover" had to explore the specific surface of a recently discovered planet. First challenge was to move on the surface and avoid obstacles that might stop robot from being able to explore. Six topics were covered: a) decimal and fractional numbers, b) diameter, c) circumference, d) distance, e) speed and f) power level. To perform the programming students used the "Move Steering" block located in the Action Blocks and also used ultrasonic sensor/infrared sensor or touch sensor to detect and avoid obstacles. Robot had to move a certain distance, avoiding any obstacle by turning right and go straight again. To figure how far the robot will drive, students had to calculate the distance covered by wheels in one rotation. This was an excellent opportunity to introduce the correlation between the diameter (doubled radius) of robot's wheel and its circumference (circumference = π x diameter). The circumference of the wheel tells the distance a wheel travels in one revolution. Students were also encouraged to calculate the distance the robot will travel for each of the other two duration variables (degrees and seconds) (ex. 1 wheel rotation-360 degrees). They also realised that power level has a major effect on distance travelled, when using the time interval in seconds (Fig. 1).

Fig. 1. A group of students testing the traveled distance

After completing the challenge, students were encouraged to draw a geometric shape on chart paper and attempt to programme their robots to follow the line of the shape without the use of colour sensor. When students finished their own version, they were asked to try more complex geometric shapes and exchange geometric shapes with other groups. At the same time, teacher was encouraging a "peer review process" so that each group was responsible for evaluating their own and others' projects. This process might have helped students develop skills in giving constructive feedback (Fig. 2).

Fig. 2. A group of students trying geometric shapes

Case 2

Other challenges were to discover a) the effect of velocity on the distance the robot moves, b) the impact of friction on a certain distance and c) the effect that changing the time of travel of the robot has on the distance it moves. Main topics covered during these challenges were: a) decimal numbers and fractions, b) speed, c) velocity, d) distance, e) graphing and f) averaging data.

As a general rule, when a robot moves at constant velocity for a certain period of time, the distance it moves is "distance = vt". We know the time our robot takes to travel a certain distance, then the velocity can be calculated as "v = d/t". With these data students plotted a graph for the velocity the robot travels and power levels applied to the motors (almost a linear relationship between velocity and power level). Students run the same experiment with the same power level on different surfaces and confirmed that certain power of the robot's motors doesn't cause certain velocity and that the external environment has an impact on the amount of friction on the wheels. A smooth surface (like glass, polished wooded floor) will have less friction, meaning the robot will travel slightly faster. A carpeted surface with thin or thick carpet, mud or concrete floor texture will have more friction, meaning the robot will travel slightly slower. When plotting the gathered data, students found out that there is no linear relationship between the power level and the time taken to travel a certain distance. When students tried to measure distance and time accurately by using stopwatches, they realised that velocity is "distance/time". They also noticed that the longer a robot travels the further it travels. Students were also encouraged to take multiple runs and gather all data to reduce the impact of the experimental error. A graphs was plotted, for the distance travelled against the time taken (the linear relationship between time and distance was obvious).

Case 3

Another challenge was to attach a marker or a chalk to the "SpaceRover" and program it to draw a shape (ex. square, triangle) on the surface of the planet. They used a large sheet of paper, markers and sticky tape to attach the marker to the front of the robot exactly in between the wheels. Three new topics were covered: a) number of sides, b) internal angle and c) external angle. Students had to understand the relationship between the number sides of regular polygons and the relationship between the number sides of a regular polygon and its exterior angle in order to calculate the internal and external angles of different shapes (pentagon, hexagon, octagon, and triangle) by using equations. To perform the programming students used the "Move Steering" block located in the Action Blocks, "Loop" Block as a way of decreasing the number of blocks needed and "Wait" Blocks.

Case 4

Students were also challenged to program "SpaceRover" to move from its starting area and navigate through a maze made of cardboard cartons by using or not using sensors (ultrasonic, touch, gyro). Students followed steps of the engineering design process to design and test programs to success. Topics were covered: a) basic arithmetic, b) multiplication, while some groups solved the maze using only basic "Move Steering" block to go forward and turn using rotations or degrees. Other groups used the ultrasonic sensor mode and "wait" block in order to wait for a specific amount of time or wait until some condition has been observed with the sensor and "Loop" block for avoiding the wall and repeat the instructions forever. The robot was driving forward, until it came within a certain distance from the wall and then turned without touching any walls along the way. Other groups used touch sensor to navigate through maze and "pushed" or "pushed/release" mode. GyroSensor and "Wait" block were also used by some groups in order to figure out how to calculate a 90-degree turn. GyroSensor is capable of measuring angles and "Change" mode was set.

Case 5

Another challenge was to use colour sensor on the "SpaceRover" and initially to a) detect surface water on the planet and then b) stay away from the planet's edges. The water was easy to spot due to its bright blue appearance. The rover had to navigate on the surface, locate water and announce that water has been found. Once water has been detected, students were encouraged to continue driving to find the next water source. In order to keep away from the planet's edges, students used colour sensor to detect "no colour". Once the rover had detected an edge they would have needed to navigate away from it.

Use of co-created content for peers' education

Co-creation by its definition is the process of product creation by members of the product's target group. In that context, an activity is construed as co-creative, in the most definitive way if the outcomes of it are used by peer groups of its designers.

The Experimental School of the University of Thessaloniki holds "Clubs Showcases", where all clubs are presented and students are able to share work products with older or younger students. This is an excellent chance for students to display the most important in the work that have been done and help their peers' practice, with their work, everything that they have learned. In that activity strand, each group of students of the "EV3 Junior Academy" was proud of presenting and sharing its work products with students from other classrooms. Students worked collaboratively and developed their own criteria (i.e. best efforts) for choosing which specific challenges to display and offer for their peers to use. In that context, this activity was construed by the students even more intensely as a co-creation endeavour.

3.2 Educational Impact Evaluation

A number of other studies examined gender differences in robotics, STEM and programming. However, in the present study the focus was focuses on the interest and attitude towards STEM content and career after the co-creative vector of educational robotics course. A paired – samples T-test was conducted to compare the interest in STEM content and careers before the intervention (before starting their training to build up and program a robot) and after the intervention in order to collect the necessary data which enabled the researchers to measure and assess students' interest in STEM and careers and also answer issues that are not directly observable.

T–Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Science	4,7000	20	,51708	,11562
	Science	3,7900	20	,48764	,10904

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Science - Science	,91000	,38100	,08519	,73169	1,08831	10,682	19	,000

There was a significant difference in the scores for Science Pre_Test (M=4,7 SD=,51708) and Science Post_Test (M=3,79 SD=,10904) conditions; t=10,682, p=,000<0,05.

From the statistical results which were obtained from the pre and post questionnaires and after doing the SPSS analysis, it becomes evident that students involvement with educational robotics facilitated a shift of their perceptions about science towards it being more attractive and engaging topic.

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Math	5,0900	20	,61721	,13801
	Math	4,1300	20	,79809	,17846

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Math - Math	,96000	,47061	,10523	,73975	1,18025	9,123	19	,000

There was a significant difference in the scores for Math Pre_Test (M=5,09 SD=,61721) and Math Post_Test (M=4,13 SD=,79809) conditions; t=9,123, p=,000<0,05.

Taking into account the statistical results it becomes apparent that students' perceptions for mathematics is improved by participating in robotics projects can change their interest and attitude towards Math in a positive way.

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Engineering	5,2300	20	,58499	,13081
	Engineering	3,9800	20	,59436	,13290

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Engineering - Engineering	1,25000	,50210	,11227	1,01501	1,48499	11,134	19	,000

There was a significant difference in the scores for Engineering Pre_Test (M=5,23 SD=,58499) and Engineering Post_Test (M=3,98 SD=,59436) conditions; t=11,134, p=,000<0,05.

In view of the statistical results we could draw the conclusion that educational robotics can enable students to adopt a positive outlook for Engineering since it engages issues of real-world problem solving and critical thinking.

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Technology	4,6500	20	1,02777	,22982
	Technology	4,0800	20	,76612	,17131

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Technology - Technology	,57000	,60966	,13632	,28467	,85533	4,181	19	,001

There was a significant difference in the scores for Technology Pre_Test (M=4,65 SD=1,02777) and Technology Post_Test (M=4,08 SD=,76612) conditions; t=4,18 p=,001<0,05.

Based on these statistical results it becomes evident that students consider educational robotics as an excellent tool for teaching Technology by linking the learning process to real-life scenarios.

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Career	5,3900	20	,87413	,19546
	Career	4,1100	20	1,00415	,22453

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Career - Career	1,28000	,73813	,16505	,93454	1,62546	7,755	19	,000

There was a significant difference in the scores for Careers Pre_Test (M=5,39 SD=,87413) and Careers Post_Test (M=4,4 SD=1,00415) conditions; t=7,755, p=,000<0,05.

Taking into account the statistical results we could claim that students' attitude towards STEM shifted to a more positive outlook.

3.3 Directly Observed Learning

Although no observation grids and other instruments were used in order to facilitate the observation of students' actions and behaviour, direct observation was conducted by the teacher resulting in eliciting essential information concerning students' perspective. Students were actively involved during the learning activities and showed responsibility and enthusiasm. They considered robotics interesting, fun, stimulating and motivating. An excellent and compelling tool for teaching Physics, Math, Engineering and Technology. Apparently, this educational project was beneficial in different aspects regarding students' learning, career and attitude. Educational robotics had a positive impact and influence on students' attitude towards learning science and can be easily integrated into school curriculum.

4 Discussion

The creative activities presented above, proved highly effective in motivating young learners towards further engagement with STEM. The results from the "Assessing Interest in STEM Content and Careers" 57 questionnaire demonstrate that the learners' perception have improved across all sectors of STEM. In conjunction with these results, the literature directly points to increased engagement when integrating co-creation activities in STEM education. It is the very core of the co-creation concept, that participatory activities lead to greater engagement of the relevant audience in marketing 58, 59 and was the rationale for its transfer to education and learning (e.g. 60, 61).

These results also demonstrate the ubiquitous nature of robotics education. As the literature also suggests 26, 27 robotics allow young learners to engage tangibly with science and technology. That way they gain intuitive experience about natural phenomena and their underlying laws that sometimes are not easy to visualize or intuit abstractly.

It must be noted that this is only one step in a greater research endeavour about the impact of co-creative robotics activities in STEM education both as teaching aids and as careers' motivators. Future steps include the comparison of co-creative robotics with classic robotics education and the relative impact of the two methods, or even more qualitative surveys about the opinions of teachers and learners about co-creative educational robotics specifically. Additionally an interesting additional research avenue is the comparison of co-creative robotics with other participatory methods in STEM such as visual programming on digital environments or through the use of immersive technologies such as augmented or virtual reality (AR/VR).

In conclusion, this work provides a solid research footing for exploring co-creative robotics as a distinct and impactful educational avenue for STEM while also building confidence and engagement for young learners towards careers in the sector.

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Appendix

STEM Semantics Survey Gender: M / F

This five-part questionnaire is designed to assess your perceptions of scientific disciplines. It should require about 5 minutes of your time. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

ID: ______________ **School:**____________	Use the assigned ID or the year and day of your birthday (ex: 9925 if born on the 25th day of any month in 1999.

Instructions: Choose one circle between each adjective pair to indicate how you feel about the object.

To me, SCIENCE is:

1.	fascinating	1	2	3	4	5	6	7	mundane
2.	appealing	1	2	3	4	5	6	7	unappealing
3.	exciting	1	2	3	4	5	6	7	unexciting
4.	means nothing	1	2	3	4	5	6	7	means a lot
5.	boring	1	2	3	4	5	6	7	interesting

To me, MATH is:

1.	boring	1	2	3	4	5	6	7	interesting
2.	appealing	1	2	3	4	5	6	7	unappealing
3.	fascinating	1	2	3	4	5	6	7	mundane
4.	exciting	1	2	3	4	5	6	7	unexciting
5.	means nothing	1	2	3	4	5	6	7	means a lot

To me, ENGINEERING is:

1.	appealing	1	2	3	4	5	6	7	unappealing
2.	fascinating	1	2	3	4	5	6	7	mundane
3.	means nothing	1	2	3	4	5	6	7	means a lot
4.	exciting	1	2	3	4	5	6	7	unexciting
5.	boring	1	2	3	4	5	6	7	interesting

To me, TECHNOLOGY is:

1.	appealing	1	2	3	4	5	6	7	unappealing
2.	means nothing	1	2	3	4	5	6	7	means a lot
3.	boring	1	2	3	4	5	6	7	interesting
4.	exciting	1	2	3	4	5	6	7	unexciting
5.	fascinating	1	2	3	4	5	6	7	mundane

To me, a CAREER in science, technology, engineering, or mathematics (is):

1.	means nothing	1	2	3	4	5	6	7	means a lot
2.	boring	1	2	3	4	5	6	7	interesting
3.	exciting	1	2	3	4	5	6	7	unexciting
4.	fascinating	1	2	3	4	5	6	7	mundane
5.	appealing	1	2	3	4	5	6	7	unappealing

Thank you for your time.
STEM v. 1.0 by G. Knezek & R. Christensen 4/2008

Fig. 3 Instruments for Assessing Interest in STEM Content and Careers