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EDUCATIONAL ROBOTICS AND COMPUTATIONAL THINKING IN EARLY CHILDHOOD - LINKING THEORY TO PRACTICE WITH ST(R)EAM LEARNING SCENARIOS

Paraskevi Foti[i]
Educational Coordinator for Early Childhood Education,
Scientific Stuff in University of West Attica,
Greece

Abstract:
STEAM enhances critical and computational thinking, problem-solving, algorithmic thinking, decision-making, through Science, Technology, Engineering and Arts, as well as Mathematics. With the contribution of Reading (Reading) and Writing (wRiting) which include recognition and visualisation, pattern formation as well as skills acquired through the use of tools such as pencil and brush, which are proven to be valuable for children's development, STREAM is now also linked to Thinking and Art in its broadest sense. Therefore, in this paper, STREAM Learning Scenarios are proposed that can be implemented within the kindergarten and primary school classroom using the BeeBot robot, highlighting its added pedagogical value and linking the theoretical framework with the playful practical implementation.

Keywords: educational robotics. STREAM Learning scenarios, computational thinking, BeeBot

1. Introduction

Educational Robotics is the computational environment consisting of one or more robots that encourage students to think better about a problem, to collaborate, and helps learners to acquire knowledge, critical thinking, and familiarity with computers and other sciences and/or arts. Educational robotics is a rapidly growing discipline in all levels of education worldwide with educational robots having the same characteristics as industrial robots taking the learner out of the confines of the computer screen and into the real world.

Robotics is designed for students to acquire analytical and synthetic thinking, and for older students, to become familiar with debugging and program optimization

[i] Correspondence: email vivifoti@gmail.com

techniques to create complex projects themselves, based on synthesizing simpler parts in a visual programming environment.

Learning computer programming from young students, such as kindergarten students, has been recognized as an activity that offers multiple benefits to the development of the individual in the cognitive domain. The use of structured thinking, helps in solving problems of different levels of difficulty, but in addition, it also enables the individual to identify his/her weaknesses and improve them, thus augmenting his/her cognitive background. As a popular and effective way for educators and as a teaching tool for introducing students to important areas of the Science, Technology, Engineering and Mathematics curricula (Johnson, 2003 & Perteet, 2005) robotics helps children to be able to learn more about the real world (Nalajala, 2003).

Learning through designing, building, and operating robots can lead to the acquisition of knowledge and skills in electrical, mechanical and high-tech computer engineering fields that are in high demand in the industry. It can promote the development of systems thinking, problem-solving, self-study and teamwork skills while promoting and encouraging students to participate in a robotics competition can provide additional educational benefits (Johnson, 2003 & Verner & Ahlgren, 2004).

This paper will refer to the main benefits of educational robotics and programming for kindergarten and primary school students and how we can integrate robotics into the daily educational program based on STREAM education. The material has been presented and is continuously updated in the eTwinning seminar Educational Robotics in Kindergarten with BeeBot (Foti, 2022) The seminar takes place in the Learning Management System (LMS), a Virtual Learning Environment (VLE) system that offers integrated asynchronous tele-education services to teachers. A lesson plan will be presented that provides the theoretical framework and can be used to organize and implement activities that integrate programming and computational thinking using BeeBot in STREAM lessons.

2. Programming in Kindergarten and first grades of primary school

Through playful programming, children learn to solve problems effectively and creatively. This can be achieved through various games and exercises, working with simple programs and/or working with robots. Children gradually develop computer skills and understand how a computer works - that is, it only executes commands given by us through various codes.

Children also develop an understanding of how a computer works and learn the type of thinking required for programming: e.g., breaking down a task into individual work steps and executing them one after the other (corresponding to 'sequencing' in programming) or repeating a series of work steps until the task is completed, concepts that will be addressed in the following sections.

Many methods and tools have been developed to allow all students to take their first steps in programming. Young learners can now experiment with programming using visual programming languages, as well as with activities that do not require digital devices, called unplugged activities, which we will address in the next sections.

Experience and relevant knowledge have created a positive climate for the application of robotics in education, as it can help to increase the quality of science and technology education in all types of schools.

While various research suggest that the use of robotics for educational purposes is an effective teaching method, more research is needed in the direction of implementing appropriate practices and strategies in order to design such learning environments. Researchers, such as Papert, argue that if robotics exercises are used appropriately, they have the potential to significantly improve and enhance instruction.

Robotic technology as an educational tool increases students' interest in programming. The use of robots to introduce programming topics is considered to have a positive effect, since it can help, among other things, to understand a precise and logical command language. Teaching programming under this approach is particularly effective as it focuses on developing problem-solving and algorithm design skills rather than on learning the programming language.

3. Robots and learning environments

As a powerful and effective way for educators and an effective teaching tool for introducing students to important areas of the Science, Technology, Engineering and Mathematics curricula (Johnson, 2003 & Perteet, 2005), robotics helps students to be able to learn more about the real world (Nalajala, 2003). Learning through designing, building and operating robots can lead to the acquisition of knowledge and skills in electrical, mechanical and high-tech computer engineering fields that are in high demand in the industry. It can promote the development of systems thinking, problem-solving, self-study and teamwork skills, while promoting and encouraging student participation in robotics competitions can provide additional educational benefits (Johnson, 2003 & Verner & Ahlgren, 2004).

Robotics and its use through the daily educational program can be applied to the following areas of the curriculum:

- Science: investigation of energy, forces, and velocity;
- Technology: programming and control of input and output devices;
- Engineering: solution development, selection, construction, testing and evaluation;
- Mathematics: measurement, use of coordinate systems, conversion and application in mathematics;
- Arts: exploring and bringing out creativity and imagination through the construction part.

The first of three roles that robots can play in the educational environment is that a robot can play an important role in programming issues. The robotic system is the focus of problem set assignments; a black box that must be programmed to create a specific physical manifestation of the process involved in computer programming.

Many studies have shown that negative engagement and retention statistics in courses such as Introduction to Programming (CS1) often stem from students' inability to see how the skills they learn can have a concrete impact on what they care about, the physical world, their friends and family (Marginson et al. 2013). The sequence on a computer screen to be able to inspire regarding a student's effort at any level of education in general, starting even in kindergarten, creating and tracing knowledge, should include elements such as playfulness and inquiry (Zhong B.C., et al., 2020).

The second role of educational robotics is that of the robot as a focus of learning. Lessons can focus on the creation and use of a robot system which, in fact, in itself during the educational process, can be a kind of target for children, in the sense that they focus on it, its functions and capabilities, what features it has, what commands it carries out, etc. (Druin A., & Hendler J., 2000).

One especially popular and favourite robot is the Bee-Bot (fig. 3) which is an attractive programmable floor robot for young children that is an easy way of introducing programming into the classroom and, its flexible nature also means that it can be used with children up to 8 years old and can help develop other areas of the curriculum in addition to ICT. Beebot is programmed with on-board buttons and can be programmed to move precisely in space by moving forward, backward, turning left and right while its simple and child-friendly layout makes it a perfect starting point for teaching control, direction (orientation) and programming language to young children (Foti, 2018, 2020, Foti, Rellia, 2020). Many schools have found that the Bee-Bot can help children develop computational thinking skills and/or reinforce concepts that other resources or methods do not use.

Robots in general can also be instrumental in stimulating general interest in science, technology and engineering, and in this way, they can show students that they too can play an active role in shaping the technology of their future. Such an application-oriented classroom has great benefits in situations where students learn best through integration, project-oriented learning, and such classes have shown significant lifelong learning outcomes in areas such as teamwork, problem-solving, and self-determination with technology-focused careers (Zhong B.C., et al., 2020).

3. STEM/STEAM/STREAM and Pedagogical approaches

"*Connect school with life and all studies are necessarily related*" (Dewey, 1910, p. 32)

Dewey's phrase above provides inspiration for educators who intuitively believe that integrating STEM/STEAM/STREAM into the curriculum creates better learning outcomes in school subjects despite the lack of experiential evidence (Frykholm & Glasson, 2005). Integrated Learning Theories and curriculum integration theories reflect

Dewey's incremental teaching tradition in which the discipline is connected to real life and becomes more relevant to students through the curriculum (Beane, 1997).

However, when we talk about STEM/STEAM education, what exactly do we mean? STEM education is seen as an educational philosophy in which Science, Technology, Engineering and Mathematics are used as an integrated approach to solving real-life problems (Priemer et al., 2019). Physical Sciences (Science), are generally regarded as being fundamental to understanding how things work in nature. Thereafter, the use of Technology (Technology) that can help facilitating human activities by modifying certain aspects of the natural world for daily needs, the use of Engineering (Engineering) as a process of designing, creating, and redesigning innovative products or processes, and Mathematics (Mathematics) skills including computation and decision making for problem-solving (Reeve, 2013) are the initial four elements of this methodology, with Arts (Art) being added which is artistic creation/expression through the arts, including expression and creativity in design. By the term Art, we do not only refer to the fine arts but also to culture, history, and the humanities in general (Foti, Rellia, 2020).

Finally, in this paper, the acronym may be supplemented by **R**, which is Reading and WRiting, when combined with thinking and art (in its broad sense), including recognition and visualization, the formation of patterns, modelling, the acquisition of a 'sense' of systems, and the skills acquired through the use of tools such as pencils and brushes, all of which have been known to be valuable in the development of young children (writing and creative thinking) (Foti, 2021)

The STEM educational approach has become a topic of interest among the international community, such as by the US government, which uses it as a way of increasing the workforce in science and technology, the contribution of which can lead to the development of technological advances, an important element for the country's prosperity (Hira, 2010). Adopting John Dewey's principle that education begins with curiosity (Savery, 2006), Inquiry- Based Science Education (IBSE) encourages young children to go through all the stages of inquiry: asking a question, developing a hypothesis, and planning how to test it, collecting data, analyzing the results, and sharing them with their peers. The IBSE method is ideal for science education because it transforms teaching into more practical: students learn how to formulate questions and answers through experimentation, while the teacher has a role as both facilitator and educator (Foti, 2021) and the usefulness of inquiry-based learning and understanding is great.

Problem-based learning is an educational method that focuses on practical and active learning, aiming to explore and seek solutions to real-world problems. Teachers try to encourage children in developing new skills, assimilating new knowledge, and using pre-existing knowledge while confronted with solving a problem (Nunes et al., 2017). Learning by conducting research and applying knowledge and skills is aimed at finding a viable solution to a defined problem and turning students into adept problem solvers in the real world.

Introducing a design activity at the beginning or at the end of a group project enables students to apply their newly acquired knowledge in order to complete an assignment they have been given, as design and purposeful research combine technological design with scientific research in the context of problem-solving (Foti, 2022, Sanders, 2009; Asunda, 2014).

Focusing on authentic problems offers students the opportunity to make connections between different subjects and to develop problem-solving, diagnostic, and critical thinking skills, including research, hypothesis testing, analysis, synthesis and deductive reasoning, to find solutions to real problems.

Subsequently, Inquiry-based Learning (IBL) is an active method that allows students to think and reason about their own thinking and to create their own learning. As such, this method does not involve memorizing or learning basic concepts, but the application and assimilation of the processes necessary for the production and development of knowledge. The benefits of the method can be summarized in that it promotes active learning, helps students to achieve deeper and more meaningful knowledge, is highly adaptable, offers more effective assessment and develops lifelong skills and competences.

To meet the challenges of learning in the 21st century, Inquiry-based Learning is considered a sustainable approach to promoting knowledge and skills, necessary to learners understand relevant elements and phenomena in their lives, both in the present as well as in the future. STEM/ STEAM with the addition of A (Arts) Arts enhances critical thinking, computational thinking, problem-solving, algorithmic thinking, decision making, creativity, and collaboration. STREAM while reading has been added to the STEM capstone (Reading) and Writing (wRiting) which are linked to thinking and art in its broadest sense, includes recognition and visualization, pattern formation, modelling, getting a 'feel' for systems, as well as skills gained from using tools such as the pencil and paintbrush, which are proven to be valuable for children's development (Foti, 2021).

5. Linking theory to practice. ST(R)EAM Learning Scenarios

Each Learning Scenario using Bee-Bot can be organized according to the suggested outline such as:

Subject: General subject area of the lesson
Subject/Study module: Specific subject or module indicated by the course.
Objective: Learning objective of the course
Summary: Short summary of the course activity.
Procedure: Instructions on how to implement the course in class and online with the simulator
Differentiated teaching: Suggested adjustments for the use of courses with both advanced and students who need effort.
Collaboration: Suggested student interaction for the course
Time Distribution: Suggested time required to implement the course.

Resources: Suggested resources for use with the course, including resources that accompany these courses, resources that teachers or students can create and Lesson Sources

Standards: Established educational standards that apply to the course and which the application of the course helps to achieve.

Many courses can involve groups of 3-4 pupils and a Bee-Bot (where possible) while because each course provides suggestions for differentiated instruction, groups can be organized according to the abilities of the pupils or students with different abilities to participate in the same groups, in order to help each other by adapting the lesson to group dynamics.

The first STREAM Learning Scenario that follows relates to the **Natural Sciences** and specifically the **Time of Year**

Title: "Seasons of the year" (Foti, 2020).

Description

Subject: Natural sciences

Subject/Study module: Seasons

Goal: To learn the seasons of the year

Summary: Students navigate with the Bee-Bot at the epoch-in-place, either on a cardboard (in dimensions 6 by 15cm) or on a transparent grid placed in images by those epochs (image 1).

Procedure

Class: We approached and discussed the thematic unit in advance: Time of Year with students. Students are then asked to identify cards that represent the seasons within the movement grid, depending on what they ask in the form of a riddle, the teacher and initially in an experiential way (movement within the grid) and then capturing the route for each season on a sheet of paper. Students then navigate Bee-Bot (if any) in the icon/or word of vocabulary that matches the season for which the teacher asks. For example, what is the season that leaves fall or is very cold?

Differentiated Directive

For advanced students, an additional element may be added that requires them to describe something that happens during this era in combination with other elements such as months or days (with images in words) or something they do. For students who try, the teacher can focus on one skill at a time, for example only in one season.

Collaborate: Students work together in small groups.

Time distribution: Multiple lesson periods as needed. The time must be 10-20 minutes.

Resources: Cardboard or transparent grid (6 by 15 cm) (figure 1). Month Cards (if we want to put other items in combination) Day Cards (if we want to put other items in combination) Season Cards (figure 2).

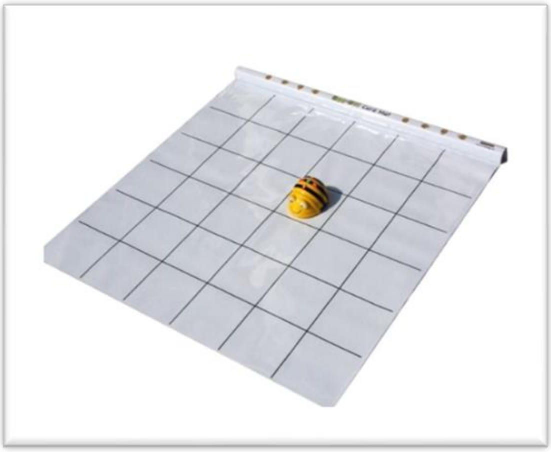

Figure 1: BeeBot Grid

Figure 2: Season Cards

Natural Science STREAM Learning Scenario for Weather
Title: "The water cycle" (Foti, 2018)
Description
Subject: Natural sciences
Subject/Study Module: Weather
Objective: To identify different types of weather and then match them with the images (Figure 3)
Summary: This Lesson plan familiarizes students with the vocabulary and images associated with the weather and then the utilization of Bee-Bot by cultivating computational thinking.
Procedure
Class: The teacher creates images and basic vocabulary words used with the weather and temperature chart in the classroom. Students need to learn the words from images with clouds, rain, snow, wind and sun, temperature zones, thermometer, wind meter and other weather tools. Photos of these objects are placed on cardboard or bottom in the transparent grid. Students are then asked to locate cards that represent the weather within the motion grid, depending on what they ask in the form of a riddle, the teacher and initially in an experiential way (movement within the grid) and then capturing the path for each different image with the weather on a sheet of paper. Bee-Bot navigates the word or image of the weather that matches the time of the day before it is written in the table.
Differentiated Directive: For this activity can be promoted mentoring by classmates.
Collaborate: Students work together in small groups.
Time distribution: Multiple course periods as needed. The time should be limited to 10-20 minutes.
Resources: Cardboard or Transparent Grid, Weather and temperature chart in class, Thermometer and other meteorological instruments, Weather Cards

Figure 3: Weather grid/cards

The STREAM Learning Scenario for the **water cycle with BeeBot (approach to the Arts and the integration of R)**
"Water cycle with paintings" (Foti, 2022)
Description
Subject/Study Module: STREAM and the Water Cycle - highlighting the A (Arts) and the R (Reading and wRiting)
Goal: To familiarize children with the Water Cycle by focusing on the Arts integrating Writing and Reading
Summary: In this Lesson plan and after students have been taught the droplet route and water cycle through a STREAM program as mentioned before. The focus is on the arts and specifically painting using educational robotics and Bee-Bot
Procedure
Class: Initially the teacher reads to the students' books on the Reading and adopting the cooperative method encourages them with pencil, colors and paper to write, copy, draw, paint what they heard and learned (Foti, 2021). Then, after approaching the lesson plan for the Water Cycle with interdisciplinary activities STREAM presents paintings on the topic. Along with the students, he/she observes, records and interprets the stages of the water cycle through the painting. He/she gives the cards to the students to put them in the correct time series on the Bee-Bot mat/motion grid and invites them to make the water path initially experimentally and then navigating the Bee-Bot with the appropriate instructions.
Differentiated Directive
For this activity can be promoted mentoring by classmates.
Collaborate: Students work together in small groups.
Time distribution: Multiple course periods as needed. The time must be 10-20 minutes.

Resources: Cardboard or transparent grid. For the specific activity cards with paintings that are related to the stages of the water cycle route (Figure 4).

Figure 4: "Water cycle with paintings"

STREAM Learning Scenario using Beebot in the Social Studies section

Title: What will we celebrate today? (Foti, 2022)

Description

Subject: Social studies

Subject/Study Module: Holiday traditions and cultural diversity

Objective: Recognition of festive and cultural symbols

Summary: This lesson plan can be used when discussing holidays, traditions and cultural diversity in general.

Procedure

Class: There has been a discussion of holidays in the school year in conjunction with the seasons. Then the holiday cards are presented which the students recognize and name with the help of the teacher. Cards with holiday images are placed on cardboard or under a transparent grid. Students are given the name of a holiday; they recognize an image showing a characteristic of this holiday and navigate first with their bodies by tracing the path on a sheet of paper and then with Bee-Bot in the corresponding image (figure 5).

Differentiated Directive

For advanced students, the course can include many symbols and traditions for holidays and/or holidays from other countries. For those pupils who are trying the most, the holidays should be covered each time until sufficient capacity is achieved.

Collaborate: Students work together in small groups.

Time distribution: Multiple course periods as needed. The time should be limited to 10-20 minutes.

Resources: Card mat or transparent mesh or cardboard. Holiday photos or images from magazines and catalogs. Holiday Photos Vacation Cards from Month Cards

6. Literature Review

A section dedicated to the significant literature resources, consulted or employed, that contributed to the study. It surveys scholarly articles, books and other sources (e.g. dissertations, conference proceedings) relevant to a particular issue, area of research, or theory, providing a description, summary, and critical evaluation of each work. The purpose is to offer an overview of the significant literature published on a specific topic.

Figure 5: What will we celebrate today?

Learning Scenario using Beebot for the **Solar System and Planets**
Title: STEM and the Earth spins (Foti, 2021)
Description
Summary: This course plan can be used when we learn about the stars, planets and solar system or bright bodies of the night sky.
Procedure
Class: Locate images of planets, moon, asteroids, sun, stars and other celestial bodies from space and discuss with the students (you can see ideas for entering this topic from the STEAM Skills Labs and the Earth turns, Foti 2021). Once the children have become familiar with this topic, then place images of the above on a cardboard or under the transparent grid of Bee-Beta (if available). Students are first driven to the corresponding image from a requested planet, performing the appropriate instructions experimentally and capturing the path on a sheet of paper. They then navigate the Bee-Bot in an image and recognize it by saying the planet's name. Students may then be asked to lead the Bee-Bot to the planets in the order of the solar system (figure 6).
Differentiated Directive: For advanced students, this activity may include astrological signs and constellations. For students who try, the teacher can enter one concept at a time: such as planets, then other objects, etc.

Collaborate: Students work together in small groups.
Time distribution: Multiple course periods as needed. The time should be limited to 10-20 minutes.
Resources: Card Mat or Transparent Mesh Images of planets, moon, sun, stars, space travel.
Constellation Cards Planet Cards

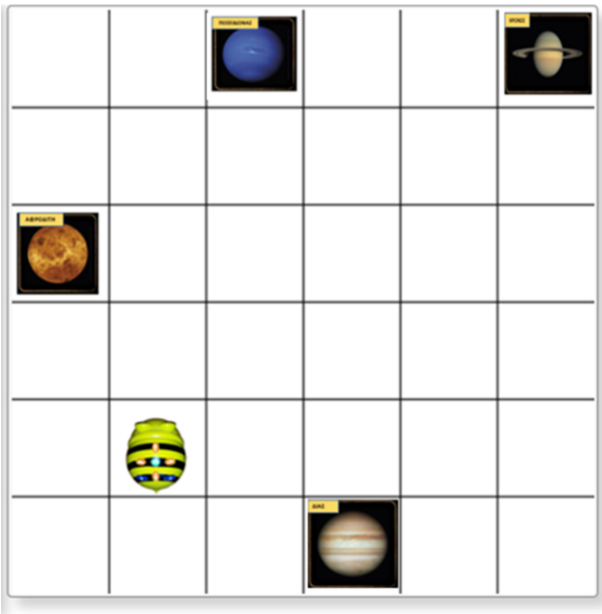

Figure 6: STEM and the Earth spins

Other Learning Scenarios using BeeBot could be about Mathematics such as:
BeeBot and Mathematics
https://content.e-me.edu.gr/wp-admin/admin-ajax.php?action=h5p_embed&id=1239573
BeeBot and Mathematics with patterns
https://content.e-me.edu.gr/wp-admin/admin-ajax.php?action=h5p_embed&id=1242276

6. Conclusion

The STEM/STE(A)M/ST(R)E(A)M approaches do not create a separation of the independence between scientific fields, but rather highlight the benefits of investigating problems through different perspectives and methodologies offered by the individual disciplines. The implementation of these approaches has an impact not only on education but also on scientific research, economy, everyday life, and the development of society in general.

This methodology offers educators and teachers the opportunity to use teaching-learning strategies based on programmes that initially involve all five (5) fields (Science, Technology, Engineering, Engineering, Arts, Mathematics) with the integration of Literacy and Reading and create an inclusive learning environment where all students can participate and contribute. In contrast, an open and inclusive environment where students can contribute and participate.

The STREAM Learning Scenarios presented leveraged the BeeBot floor robot, highlighting the added pedagogical value with a common element: play. While playing, the children will experience preparatory activities that will allow them to become familiar with robotics and develop their initial perceptions of robots. This step is important so that the child can experience robotics in a meaningful way while promoting skill development. It is very important to explain to children that robots have three things in common:

They have a body or processor.

They run one or more programs.

They are equipped with sensors to react to the environment without human intervention.

To facilitate understanding for children, we can make comparisons with our body, which is the container, our brain that executes programs with reflection and decision making guided by sensors, our senses. Depending on what we see, what we hear, what we touch, what we feel, that will guide our actions.

Young children can program and watch the robot respond. They understand that we control the robot through the actions we input into it and become familiar with algorithmic and computational thinking.

Conflict of Interest Statement

The author declares no conflicts of interest.

About the Author

Paraskevi Foti is an Educational Coordinator in Regional Directorate of Primary & Secondary Education of Attica and formerly Head of the 4th Kindergarten of Agia Varvara. She has studied classic piano and theory at the National Conservatory of Athens, and she has completed her master's degree (MEd) in Intercultural Education and Management of Diversity and a second one in Specialization in ICTs and Special Education: Psychopedagogy of Inclusion. Her second degree is in Psychology from National and Kapodistrian University of Athens with a specialization in Pedagogical Psychology and her doctoral dissertation (PhD) is entitled: "The contribution of ancient Greek language to art and language of Aesop and the added value of ICT Technology" with an Excellent degree. Now she is a Post Doctoral Candidate in STEAM education in University of Western Macedonia. Her first book, "Otherness, Prejudice and Stereotypes in the School Class. Teacher Management Methods" was selected as a University chart at Harokopeio University of Athens and she has participated in a collective volume ondigital educational scenarios (ed. Grigoris, 2017). Another book is "Understanding our Language, Ancient and New Greek through Aesop" (ed. Grigoris, 2020), and the next one is entitled "STREAM and Educational Robotics for children aged 3-8 years" (ed. Grigoris, 2020). She has published in many international and national conference proceedings as

well as in scientific journals and has a keen interest in Information and Communication Technologies and their contribution to the teaching process and in STEM Education, as a Scientix Ambassador (European Commission). As an eTwinning and Moodle trainer she supports open-source software in the classroom. She is a teacher of Educational courses at the University of West Attica, Department of Education and Care (since 2011) and at the Postgraduate Program of Pedagogy through Innovative Technologies and Biomedical Sciences. Her email is vivifoti@gmail.com and pfoti@uniwa.gr and her website is https://blogs.sch.gr/3syn60-at3/.

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Appendix: Elements

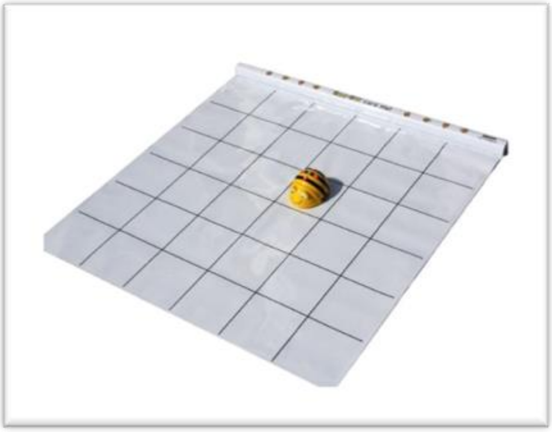

Figure 1: BeeBot Grid

Figure 2: Season Cards

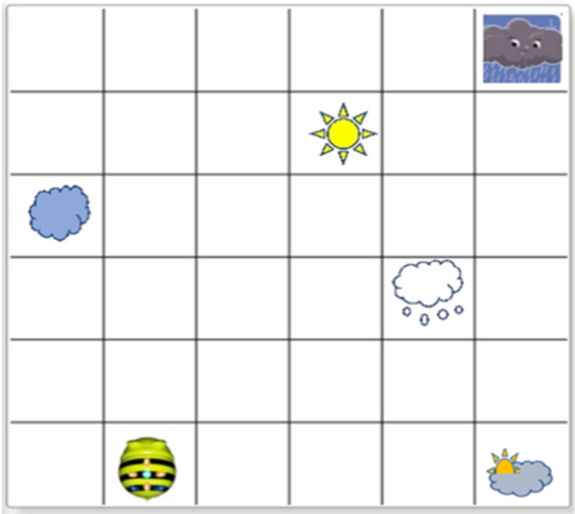

Figure 3: Weather grid/cards

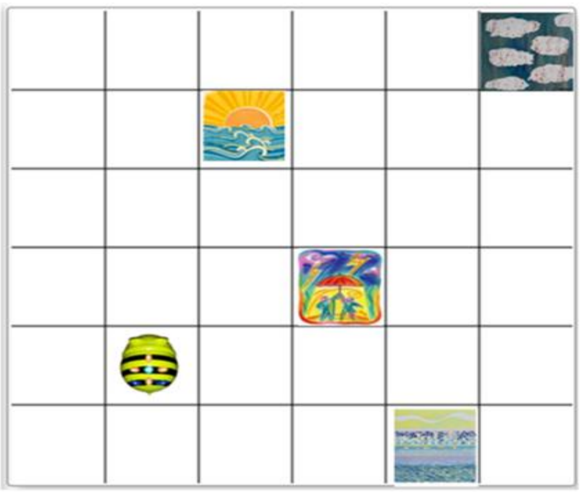

Figure 4: "Water cycle with paintings"

Figure 5: What will we celebrate today?

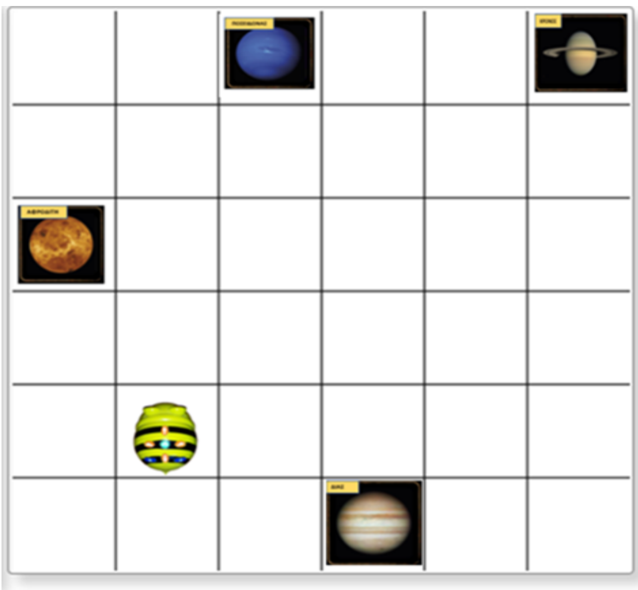

Figure 6: STEM and the Earth spins