Guidelines for teachers

Project RoboScientists

Content

“*Nothing could be more absurd than an experiment in which computers are placed in a classroom where nothing else is changed* (Papert, 1993, p. 149).”

Introduction

Educational robotics (ER) facilitate smart learning because technology is used to empower learners to develop innovative talents that involve computational thinking, programming skills, and collaboration in the construction of robots. According to Alimisis (2013), educational robotics can really improve the learning approach, but the solution is not to only introduce robots in didactics. He notes how learning robotics is not the goal to achieve in educational robotics. Instead, a didactic curriculum update, to include robots as tools, have to be made. He writes “the role of Educational Robotics should be seen as a tool to foster essential life skills … through which people can develop their potential to use their imagination, to express themselves and make original and valued choices in their lives. Robotics benefits are relevant for all children …”.

Educational robotics is no longer a novelty in the educational environment, since Paperts (1980) invented the LOGO programming language (60s of the 20th century), which was suitable for children, to promote their use of technology and programming skills, many years have passed. There have been times when these were separate initiatives when enthusiasts used educational robotics. Then, for a while, educational robotics was in a plateau, with no sharp turnaround. There were enthusiasts who used these ideas in their work but lacked popularity until Lego introduced Lego Mindstorms to the world in 1998 as a result of a collaboration between Lego and Papert (Waterson, 2015), which can be considered a renaissance of Educational Robotics the world rediscovered it and began to invent various new robotics artifacts, new searches for their use in the educational environment to help them learn, master new and complex concepts. The Erasmus + project “Motivating Secondary School Students Towards STEM Careers Through Robotic Artifact Making (RoboScientists)”, from 2018-1-PL01-KA201-051129, will develop materials to help teachers use ER in a creative way to motivate students towards STEM careers. This is necessary because educational resources in school education are often developed according to a widespread misconception that robotics is “hard” science and is suitable only for gifted children or science and technology-oriented students. This misconception is often coupled with gender-biased views that robotics subjects are only for boys and poses real obstacles to the adoption of robotics in education (Alimisis 2013). There are many examples where the acquisition of STEM is associated with robotics activities initially organized as after-school activities, special projects, etc.

The new educational approach STEAM (Science, Technology, Engineering, Art and Math), where part of creativity is added by adding the concept of Art, allows to use robotics in school as practical activity to encourage the students to learn and apply theoretical knowledge in the science, technology, engineering, art (creativity) and mathematics. A combination of robotics using STEAM and DIY (do-it-yourself) approaches can be very effective to help students to improve basic skills like logic and communication.

It should be noted that there is a distinction between Robotics in Education (RiE) and Educational Robotics. RiE is a broader term referring to what Robotics can do for people in

Education. For example, it can help impaired students to overcome limitations or it can help teachers to gain attention or to deliver content to pupils. Educational Robotics (ER) refers to a specific field which is the intersection of different kinds of expertise like Robotics, Pedagogy, Psychology (Scaradozzi et al, 2019).

1. Pedagogical ideas underpinning the RoboScientists intervention

The pedagogical orchestration of educational robots include teacher led demonstrations, guided workshops, or discovery and problem-solving scenarios. The learning activities are often multifaceted including design, construction, and programming for solving a specific problem.

Empirical research focussing on educational robots have documented a greater engagement of students in STEAM learning activities. Other empirical studies show support for critical thinking and complex problem solving as well as increased comprehension of complex concepts and procedures. In addition, as artificial intelligence for robots is further developed, data analytics, adapted behaviour to specific learning needs and enhanced social interaction including educational robots are currently a focal point of empirical research.

Educational robotics is based on the ideas of Constructionism, developed by Papert. However, these ideas do not come from the empty space, but are based primarily on the ideas of constructivism (Piaget) and social constructivism (Vygotsky) (See fig.1). The idea of Constructivism (Piaget) implies that children's thinking processes evolve from the simplest to the most complex, that the child cannot acquire the knowledge if they have not yet developed the necessary thinking operations, so learning can take place only step by step, where the teacher successively assists the child in learning and organizes the learning process according to the child's development. Relatively similar ideas are included in Theory of Social Constructivism (Vygotsky), where children learn by sequentially acquiring new knowledge in the social environment, interacting with peers, testing their own knowledge in the environment, sometimes making mistakes, and sometimes validating their own knowledge, and this learning process takes place through language (as a means of communication). The Papert went a step further because he believed that in order to help children develop thinking processes, to help them understand how certain mechanisms work, they themselves had to deal with them and must operate in all processes. He developed Constructionism ideas, based on the ideas of Constructivism (Piaget and Vigotsky), that thinking processes evolve gradually, but with the addition of a hands-on principle explaining to children's complex concepts (mechanics, physics, programming, etc.). Educational robots, as a new type of learning manipulative, engages students in hands-on activities: students learn concepts while they are doing some activities and projects. Hands-on nature of robotics creates an active learning environment and increases conceptual understanding of subject matter.

In all these theories, the authors believe that children's thinking evolves from simplistic concepts to more complex ones. They all agreed that the key steps were:

1. The ability to emerge from here-and-now contingencies (characteristic of practical intelligence);

2. The ability to extract knowledge from its substrate (i.e., from contexts of use and personal goals);

3. The ability to act mentally on virtual worlds, carrying out operations in the head instead of carrying them out externally (Ackermann, 1991).

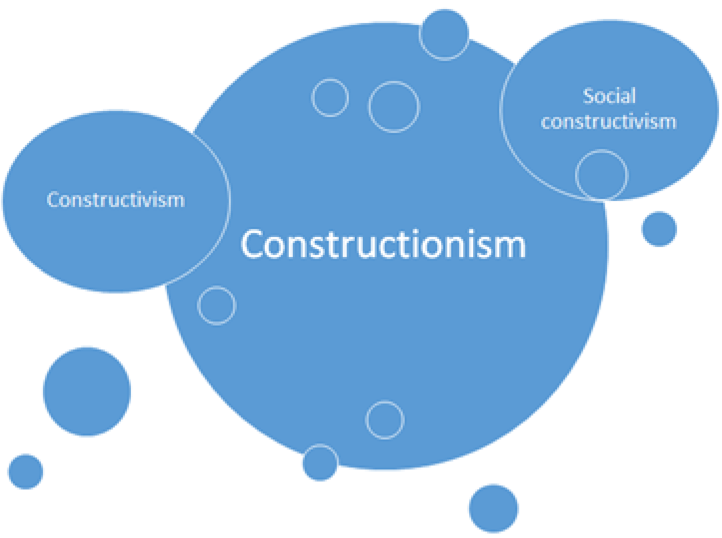


Figure 1, Constructionism among constructivist theories

To help the children construct their own knowledge, Papert worked together with them, taught them to construct, taught them to put together different mechanisms, taught programming, but this learning was organized from simplified mechanisms to the most complex to practically demonstrate their work rather than just explaining them sequentially. Papert created many different simplified solutions, such as the LOGO programming language, later Lego Mindstorm, to ensure that children can become their own knowledge builders and give them the opportunity to experience the joy of running, the joy of creation.

The pedagogical goal for the construction of robots is to awaken students' attention and creativity, promoting the motivation to learn certain content in a pleasant and exciting way, as well as encouraging the reuse of materials that would simply be discarded.

2. Learning taxonomy

As well as the world and society are continuously changing, pedagogy as a science is constantly evolving. Teachers are looking for new and better ways to teach and involve students in the educational process. In 1956, there was a significant turning point in educational science when for the first time was published an educational taxonomy known as Bloom’s Taxonomy, that was developed under the leadership of educational psychologist Benjamin Bloom (Bloom et al., 1956).

This taxonomy included three domains:

- **Cognitive domains,** organized in sequence of how knowledge is acquired, starting with memorizing facts, then understanding, analyzing, using, creating, and evaluating the progress,
- **Affective domains,** which include the emotional response to learning, its acceptance or rejection, influenced by interest, attitude, appreciation, values, and emotional ties.
- **Psychomotor domains,** that include the sensory and physical abilities to work with certain materials or to perform activities that require the ability to coordinate their movements in a specific way.

In 2001 scientists developed revised Bloom’s Taxonomy that was based on years of research. The revised taxonomy is widely known as Anderson’s Taxonomy that was categorized as follows: remembering, understanding, applying, analysing, evaluating, and creating new knowledge, new ideas (Anderson et al., 2001).

The main idea is that knowledge evolves from simplistic concepts of thinking, such as memorizing and remembering certain facts, to the fact that this information can be used to carry out analytical activities, synthesize various pieces of information, and create new, complex thinking concepts that help the individual to learn (metacognition).

The ideas developed by Papert that students experiment, learn, and construct their own knowledge, which is widely used in educational robotics classes, are also developed in a similar way to that of the learning taxonomy, but the innovative idea of Papert was to give students the opportunity to work with a variety of artefacts, develop them themselves, and test their knowledge in action.

Nowadays, as educational robotics is gaining popularity, more and more robots are being developed, programs that can be programmed into robots without understanding the logic of learning taxonomy, where students are progressively moving from simpler ways of thinking to more sophisticated thinking operations, where student development is sequentially guided, where the Papert added the practical work. It is also important to understand what educational robotics has to offer and the types of knowledge and competencies it helps to acquire, which will be discussed in the next section.

3. Educational Robotics Taxonomy

Scaradozzi and his colleagues (2019) have sought to outline the ways in which robotics is or can be used in education today. They distinguish (educational robotics) ER as one of the different types of robotics that can be incorporated into both formal and non-formal education (educational robotics ER / Robotics in Education RiE). It can both be included in the learning process activities to assess progress and it can also be incorporated into the learning process without formally assessing the progress achieved. The authors also advise on different ways of evaluating robotics activities (see Figure 2). The aim of this project is to focus on the educational robotics ER used in the formal learning process by incorporating robotics activities into the classroom to promote students' interest in STEM sciences.

The work of Scaradozzi and colleagues is essential because it allows you to structure the various robotics activities and to understand that the robots used in the classroom to perform certain tasks, for example, helping a student with special needs to move is not an educational robotics but an assistive robot that is used in an educational environment. Pupils working with educational robotics can also develop solutions that can be considered as other types of robots, but in that case it will be the result of the learning process, reaching the highest level of learning taxonomy, reaching the highest level of learning taxonomy, ability to create new knowledge, new ideas, innovative products.

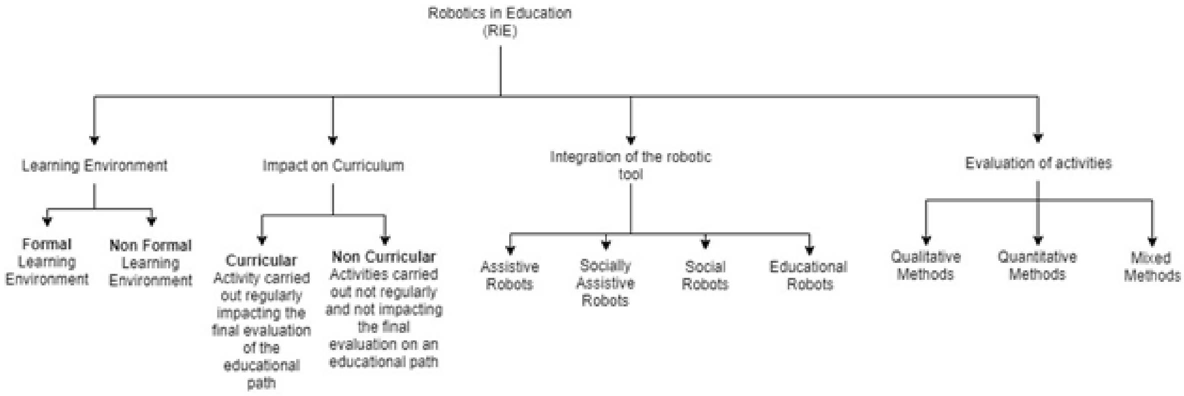


Fig.2 the proposed classification for Robotics in Education (RiE) ***(David Scaradozzi, Laura Screpanti, Lorenzo Cesaretti, 2019)***

While D. Catlin (2019) and his colleagues have developed EduRobot Taxonomy (See Figure 3), where they have tried to classify available robots according to their types, providing that in education, as any educational robot can be used, only choice depends on the learning objectives.

If your goal is to teach the basics of educational robotics and how to program them, we recommend choosing the ones that fit the *build bots* category, because the use of such robots in the learning process is more relevant with Papert's ideas that students themselves operate and construct robots, including programming, to construct their knowledge.

Fig.3. The type, class, and subclass for EduRobot Version 2.02. *(Catlin et al, 2019)* For further information: www.robots-for-education.com.

4. Knowledge development with ER

Teachers choosing to work with educational robotics, have to keep in mind that learning is a sequential process whereby knowledge is acquired gradually and in order to achieve this, both the peculiarities of student development, the learning taxonomies and the pedagogical principles must be respected and to support students as they construct knowledge.

One example that can be used successfully in teaching is the principle of 9 steps by Gagne and colleagues (Gagne et al, 1992), which should be followed:

1. ***Gain attention of the students*** - when starting to use educational robotics in the learning process, it is first necessary to attract the attention of students, which can be done with something new, interesting information and more often robotics seems interesting and exciting to students, so no other information is likely to be needed, unless they are

already have lost their motivation to learn, and for whom the knowledge that they will need to learn robotics can cast even greater doubt on their desire to learn and succeed. In such cases, the teacher's role is to provide information so that students avoid these concerns, which involves the use of words and terms that are clear to all students participating in that class.

2. ***Inform students of the objectives*** - It is necessary to inform the students about the learning objectives and the activities that will be done to achieve them. Here, too, it can be predicted that students will have an interest in educational robotics, but keep in mind that when students have a lack of knowledge of some concepts (programming, physics, mechanics) that are important to acquire the knowledge that to build robots, these achievable learning goals may seem difficult or even unattainable for them, and he or she can avoid specific activities in any way, so the task of the teacher is to make sure that all students understand the goals to be achieved and encourage students to get the support they need and set learning objectives.
3. ***Stimulate recall of prior learning*** - at this stage, the teacher stimulates the discussion of prior knowledge and invites students to remember what they have learned in the past and which may be useful in learning new knowledge about robotics. Here too, it must be remembered that there are motivated and knowledgeable students who will have this prior knowledge and will be happy to engage in discussions that can make the teacher confident that everyone present has this knowledge. However, it should be kept in mind that there may be students in the classroom with lack of previous knowledge, and discussion of other students' knowledge and concepts that are not clear to them, may raise even more doubts about their abilities and contribute to the development of avoidance motivation. The teacher's task is to carefully watch what is happening in class and understand which of the students involved in the discussion and have the necessary prior knowledge, but even more important are those students who are not involved in the discussion, so that the teacher can track whether or not this involvement is based on the introverted nature of the student when he or she has the necessary knowledge but is not ready for public discussion, whether it is a student who does not want to demonstrate his lack of knowledge.
4. ***Present the content*** - the teacher tells and demonstrates the content of the study. Educational Robotics lets you pick constructive robots, where the teacher can show you a ready-made robot and tell students how to build and program it by themselves. Also at this stage, the teacher has to look closely at the students in the classroom to see who is ready to act and support each other, collaborate in groups, and those who would like to work but do not want to do it in groups and those who would like to avoid learning new knowledge, because they have no confidence in themselves and are afraid to do something new so that they do not look incompetent in the eyes of others. The teacher should develop this type of classroom scan as it is needed to provide the necessary support for each student.
5. ***Provide learning guidance*** - getting familiar with the training contents, students can start up and the teacher's role is to ensure that they are available for different types of support. They can be instructions for specific activities, they can be peer learning forms where students help each other and work in groups, it can be an individual explanation to a student. This is the stage where the teacher's job is to see if the students in the groups are equally involved? Isn’t it the case that one student dominates the others and does

everything by not allowing the other students to become actively involved? When identifying such a problem, it is up to the teacher to understand whether it is just a temporary change of role, or if one of the students does not understand and learn from the most active student, and then it is a supportive learning process. But there may also be situations where he is an introverted learner with the knowledge to continue working and developing new ideas, to design and program something new, but he is not ready to work in groups.

The teacher's job is to accept that even such students can be, and then try to provide these students the opportunity to work individually on tasks. The situation may be more difficult with students whose previous knowledge is insufficient to understand the concepts they are learning (electricity, mechanics, programming, etc.) and observing other pupils who are clear and can do even more causes him to be unsure of his abilities and leads to the risk of exclusion. Teacher support, diversification of instruction, slower pace of learning, and teacher recognition can help here to build confidence in the student. It is important to remember that meeting students who have lost motivation for learning may not help to offer an interesting and exciting way to learn something, as this seems to them to be another challenge which can lead to the illumination of their incompetence. It also does not help if the teacher praises (to confirm good performance) the student a few times, as this feeling of incompetence is usually formed over a longer period of time, so it may take quite some time for that feeling to change. This will be a lengthy process where the student's self-confidence will need to be strengthened slowly, step by step. Educational robotics can be of great help to such students as they can, through practice, acquire knowledge of concepts that they have not yet clearly understood. If a teacher manages to convince such students of his potential success, to become interested in overcoming his first fears, then practicing robotics, switching electrical circuits, programming various robot activities, taking responsibility for his own learning, can provide a significant turn in the student’s attitude towards STEM subjects, especially for students with reduced learning motivation and dislike of complex technical concepts.

6. ***Elicit performance (practice)*** **-** the teacher's task is to allow students to work in practice, so that they gradually consolidate their prior knowledge as well as develop their sensory skills in connecting various details. At this step, the teacher's role is to observe students practicing and those students who have mastered the entire offer sophisticated tasks to challenge the new solutions in order to avoid that they are slowly starting to get bored, because everything has already been acquired. And for students who are slow-working or who have so far had a desire to avoid learning new knowledge and who have finally become enthusiastic about robotics, must be allowed to practice to consolidate newly acquired knowledge (skills to match robot parts and develop a program)for such practical activities, with already learned and known things, will help students with low levels of confidence in their abilities to build their self-confidence and form the basis for their desire to be active and active in the future.
7. ***Provide feedback*** **-** the role of the teacher at this stage is to continuously provide feedback on what has been done, and this is not new to the work of teachers, but here are some things to keep in mind:

1. students who are actively engaged, looking for new solutions, show willingness to learn and act, receive feedback from the process itself, because in educational robotics activities, they have developed artifacts that work, move, can play a variety of sounds, and demonstrate that knowledge is of practical value. In this way, robotics artifacts are like learning agents;
2. students who have low confidence in their own abilities, which is to avoid the acquisition of new knowledge, because to be developed avoidance motivation, are the ones who need continuous feedback. Sometimes it will be commendable, sometimes it will be an exhilarating replica, sometimes it will be a help to overcome some difficulties, but sometimes a smile, a gesture or positive body language will suffice. The key is to keep these students constantly in the teacher's eyes and remember that these changes, from self-doubt to self-confidence, are gradual.

8. ***Assess performance -*** Students want their work to be valued. Sometimes a simple feedback is sufficient, but sometimes a formal evaluation of the work is required. The results achieved can be summed up, with marks (points) for quantifiable achievements, or formally, in terms of the pupil's work, efforts and difficulties. The results achieved can be summed up, with marks (points) for quantifiable achievements, or formally, in terms of the students work and the efforts and difficulties they have overcome. If educational robotics is integrated into the formal education process and students need to demonstrate their knowledge of some concepts (physics, mathematics, programming), then the knowledge acquired is evaluated according to formal knowledge assessment criteria (but it is important for teachers to keep in mind like those with low self-confidence). It is important to remember that assessment is one of the motivating factors in the assessment process, so it would be important to look not only at the quantitative increase in knowledge, but also at the students' progress towards themselves. However, if educational robotics is introduced in a learning process where formal assessment is not necessarily required, the teacher should keep in mind that job evaluation is one of the motivators, so it is necessary to provide students with an assessment of their performance from time to time. but in this case it would be advisable to avoid summative formal assessment by focusing more on the progress achieved and providing that each student is seen and positively evaluated.
9. ***Enhance retention and transfer to the job -*** šajā posmā ir paredzēts, ka skolotājs palīdz skolēniem izmantot apgūtās zināšanas praktiskā darbībā. Educational robotics that take place through the Constructionism paradigm when students are continuously learning hands-on practice, ensure that this step, designed by Gagne and colleagues, is already included in the previous steps and that no specific activities may be required here. However, at this stage, the teacher may suggest to the students to develop a specific solution that is needed by the community or the individual. For example, a fire alarm system, watering system, traffic light system for the city, etc.

5. Computational thinking

The term was coined by Jeanette Wing in 2006, at Carnegie Mellon University to describe an approach to problem solving.

Computational thinking is not a skill, but a range of concepts, applications, tools and thinking strategies that are used to solve problems. You can practice Computational Thinking without using a computer.

Computational thinking (CT) is the use of problem-solving methods, by means of formulation problems and solving them in the same manner a computer could. Computational thinking and programming are at the center of the debate on exploiting the full potential of ICT which emerged as a new concept to help prepare children for future challenges in an increasingly digital world. Indeed, these skills are now considered by many as being as fundamental as numeracy and literacy.

According to Arfé and colleagues (2020) from the University of Padova, computational thinking as a skill consists of the following problem solving abilities: analyzing the problem space, reducing the problem difficulty by decomposing it into smaller units, develop an algorithm or plan, or more specifically a set of instructions or steps to undertake for its solution and finally, to verify that it has reached its goal.

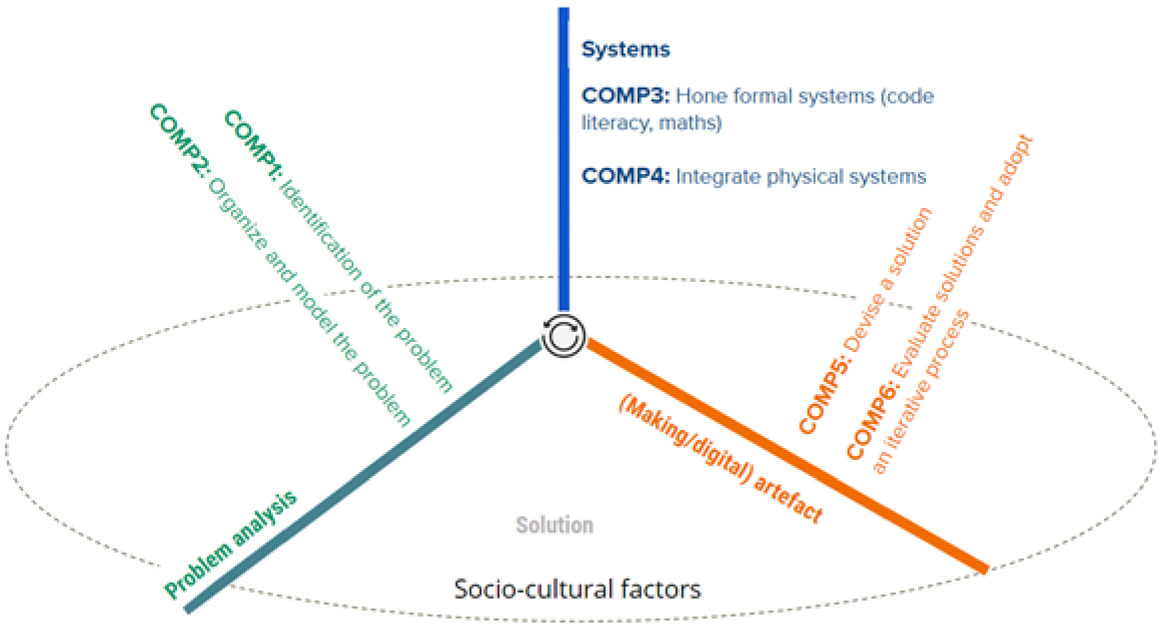
In this sense there are four computational thinking concepts: algorithm, sequence, loop and conditional or if statements that correspond to certain abilities in children which refer to understanding and using abstraction, sequencing, decomposition and debugging.

CT learning activities are believed to encourage positive technological development through the enhancement of six behaviors (Bers, et al 2019) also known as the 6 “C”: Communication, Collaboration, Community-building, Content Creation, Creativity and Choices of Conduct.

Working with the aforementioned six behaviors and abilities will encourage children to have a better sense of confidence and competence and be equipped to participate in a digitally - literate community, and as a result, be better integrated socially into their adult life.

Ultimately, the goal of CT learning is to stimulate cognitive development such as abstract thinking and reflective reasoning in early years in hopes of laying foundations for understanding more complicated computational processes later on in life, that will make future adults more technologically informed and to even consider a genuine career in the domain as digital and software creators.

Computational thinking engages components related to the analysis of the problem situation and the way the subjects organise and model the problem (problem analysis axis), honing formal systems with the use of a certain programming language and the integration of physical systems (systems axis) and the devices of an intermediate solution, its evaluation and improvement (creation axis).



Computational thinking components (Romero, Lepage, & Lille, 2017)

Computational thinking engages components related to the analysis of the problem situation and the way the subjects organise and model the problem (problem analysis axis), honing formal systems with the use of a certain programming language and the integration of physical systems (systems axis) and the devices of an intermediate solution, its evaluation and improvement (creation axis). When learners are only engaged in coding they develop knowledge related to the systems, but they do not engage in the full process of analysis, modeling and iterative creation of a solution (Romero, Lepage, & Lille, 2017).

There are four major facets to computational thinking:

1. Decomposition: breaking a problem down into smaller parts;
2. Pattern recognition: finding similarities and differences between the different parts, to be able to make predictions;
3. Abstraction: the ability to find the general principles behind the parts and patterns in problems;
4. Algorithm Design: developing step by step instructions to solve different problems.

An advantage is that early contact with computational thinking challenges can inspire pupils to choose more STEAM-related fields of study. However it is important to note that not all the children will become programmers, engineers, architects or experts in other fields where we assume that computational thinking is needed. It is important to support the development of computational thinking to teach how the world is constructed, how the digital technologies are working but it shouldn't be narrowed down to programming. Wing especially stressed critical thinking and creativity. Activities with robotics can support the development of all aspects of computational thinking and we must support that process.

Catlin (2019) summarized ideas of computational thinking in a table (see table 1)

Table 1 Computational Thinking Skills based on J.Wing (Southampton University, 2013)

Skill	Competencies
Abstraction	Dealing with complexity by stripping away unnecessary detail.
Algorithm	Identifying the processes and sequence of events.
Decomposition	Breaking complex artefacts, processes or systems into their basic parts.
Generalisation	Identifying the patterns and shared by artefacts, processes or systems.
Logical Analysis	Applying and interpreting Boolean logic.
Evaluation	Systematically (through criteria and heuristics) make proven value judgements.

This table represents a fuller version of the computational thinking than shown in much of the literature.

6. Motivation

The motivational factors are those which can be taken in mind when organizing ER activities because ER requires active learning strategies, students can try all the knowledge development steps by themselves and it supports their motivation to get deeper knowledge and develop higher metacognitive competencies. One of the models for supporting motivation is ARCS model which can be used to keep students motivated (Keller, 2010):

i) Attention

There are three basic ways to get attention: perceptual arousal, inquiry arousal, and variability. Perceptual arousal is used to gain and maintain student attention by visually attractive graphics. After getting the first interest, inquire arousal comes. Inquiry arousal is a strategy to stimulate and maintain the interest through information-seeking behavior with the use of questions and problems.

ii) Relevance

Relevance is the second factor of the ARCS model. It is the strategy that meets the learner's needs with the course material. There are three different methods to execute this factor: familiarity, goal orientation and motive matching. Familiarity is a way that uses concepts and examples that connect and relate the course material with the learners' experiences to help them understand the topic better. Goal orientation is relating the course material to the learners' objectives. It can be done by providing statements that present the goals and utility of learning the course material.

iii) Confidence

Confidence is the third factor of the ARCS model. Confidence is the methodology of giving the learners with positive expectations for success to be motivated. There are three different methods of building confidence in the learner: Expectancy for Success, Challenge Setting, and personal responsibility. Expectancy for Success is the Learning requirements and the expectations criteria that the learners need to meet to succeed. Challenge Setting is a strategy to provide the learners with enough challenging opportunities so that they can be confident in their competence through allowing the teacher to provide feedback on the learners' process. Personal responsibility is the strategy that connects the learning success to the learners' personal efforts and abilities

iv) Satisfaction

Satisfaction gives a positive feeling about the learners' achievements. The three types of enhancing satisfaction are: intrinsic reinforcement, extrinsic rewards, and equity. Intrinsic reinforcement is what the learners need to be aware that the material will benefit them. Extrinsic rewards are rewards awarded to the learners that are pioneers to realize their achievements. It is feedback that is given by the teacher based on success. Equity is the idea that there is justice and equal treatment. It is the idea that the rewards need to be consistent based on the accomplishment

7. How to bring ER in schools?

Learning Environment: formal or non-formal projects

D.Scaradozzi and his colleagues (2019) believe that students can learn in a variety of settings (e. g. at school, at home, in an outdoor environment). Each setting is characterised by the physical location, learning context and cultures. Usually, each setting holds specific rules and ethos to define relationships, behaviours and learning activities. Formal education is usually delivered by trained teachers in publicly recognised organisations providing structured activities and evaluation. Non-formal education can be a complement to formal education, but it may be apart from the pathway of the national education system, consisting in a shorter activity. Usually, non-formal activities lead to no qualification, but they can have recognition when they complete competences otherwise neglected. Formal environment is where formal education usually takes place (e.g schools) and non-formal environment is where non-formal education usually happens (e.g. private houses, company's headquarters, museums).

Teaching methodologies, spaces, furniture and many other variables influence the outcome of an ER activity, but they are out of scope in this part of the classification, which intends to make a distinction at a broader level.

School curriculum impact: curricular or non-curricular projects

The way activities are integrated in education strongly impacts their design and their expected outcomes. Activities carefully designed to fit the curriculum needs, carried out regularly in the classroom to support students' learning of a concept and whose evaluation is recognized in the final evaluation of the school on students is a curricular activity. Seldom activities organized to better support the teaching of particular concepts, both inside and outside the classroom, and that lead to no final formal recognition are non-curricular activities. There may be activities performed at school (formal learning environment) that do not account for the final evaluation of the student (non-curricular activity). On the other hand, there may be an activity performed outside the classroom environment (non-formal learning environment) that is recognised into the final evaluation of the student provided by school (curricular activity).

8. Some ideas/examples

What do you need to start in educational robotics and what you can use?

It is possible to start robotics in the classroom at different levels depending primarily on what kind of skills the educators want to teach, how deep in the study and comprehension of these skills they want to go and, of course, what budget they can devote to the project. Many possibilities are available today on the market: from a ready to use robot, to a robotics kit, to the possibility to create a robot from scratch and few components.

What are the differences between these possibilities?

- A ready to use robot can be a less time-consuming solution but it is not a scalable solution consequently it requires more budget. Moreover a ready-to-use robot can allow a teacher to work on a specific competence or skill but it can be more challenging to apply it in an interdisciplinary project.
- A kit to build a robot is a good solution if you want to realize a workshop with a maker's approach. Assembling a robot allows students to apply hands-on work, but also engage in skills such as reading comprehension, following instructions, and communication. It's an excellent practical exercise. Robotics kits are at affordable cost.
- Making a robot from scratch can be economical, but time-consuming. Learning how to make a robot is a challenging, but rewarding experience that requires lots of trial and error and learning by doing. A maker-activity includes several steps,

research and choices to make : from how to design the robot, where to find the components, then how to code the main program.

Use the following questions to help determine the best fit for introducing robotics in your classroom.

1. How much time do you have for the project?
2. Do you have a specific budget?
3. What do you want to work in terms of skills and competencies ?

Technical preliminary knowledge

Preliminary knowledge in electronics, like the Ohm law, are suitable but the educator can always include this knowledge as part of the educational path. In that case, students will discover the law during the activity. For instance, let’s think about the possibility of creating their own robot using an open source hardware platform, like Arduino (refer to the next paragraph). In order to understand how this platform works and how the input and output pins work it is a common exercise to use at first the board to control an LED light. This exercise can be used to introduce the Ohm law to students or the Kirchoff’s circuit law, at the same time it allows the students to understand how the pins in the Arduino board work, how to connect an external component to the board, how to communicate with the Arduino board through a specific software (please refer to the next paragraph for more information about the Arduino IDE).

For a more advanced workshop the teacher can go through on how an LED light works, to study the Joule effect then to shift to thermodynamics laws and landing on a discussion about energy production, environmental impact of the technology.

9.Evaluation of learning outcomes

When assessing students’ achievements, the increase of knowledge often comes to the fore, and thus the impact of innovative pedagogical activities is assessed through the prism of quantitative indicators of knowledge growth, knowledge expansion, knowledge deepening, or acceleration of knowledge acquisition.

Evaluation in activities could be carried out by using a qualitative method, a quantitative method or a mixed-methods approach. Qualitative methods in education pertain to research and to everyday practice. Teachers and researchers can analyse essays, focus groups, scenarios, projects, case studies, artefacts, personal experiences, portfolios, role play or simulation and many other output of the activities. This is a deep and rich source of information on students’ learning, but sometimes impractical in a crowded classroom and always vulnerable to personal biases or external influence. On the contrary, quantitative methods are easier to replicate and administer. They try to summarize with numbers the outcome of an activity. Common tools in quantitative methods are based on questionnaires, tests and rubrics. Anyway, experiments and empirical methods should be applied to prove these methods valid, reliable and generalizable.

Moreover, a quantitative evaluation in education is often deemed as poor and reductive. Lately, researchers in education have been overcoming the historical distinction between qualitative and quantitative methods to exploit the beneficial aspects that both methods provide. Researchers have been proposing the mixed-methods approach as an appropriate research method to address problems in complex environments, like education. The choice of mixed-method design is usually well motivated because it could imply a lot of work as it requires that both quantitative and qualitative data are collected. In the last few years some novel real-time techniques have been introduced to monitor students during their activities. Technology and artificial intelligence seem to be promising in providing feedback on students' learning and in integrating both qualitative and quantitative methods of assessment. Moreover, it could be deployed into the classroom seamlessly and give responses on the activity to support the assessment.

Educational robotics also shouldn't be taken as providing a panacea for all the problems that exist in education. However, an important principle of inclusive education is 'no child left behind', and everyone should remember the principles of the zone of proximal development (Vygotski, 1987), principles of motivation (Bandura, 1986; Migdley & Urdan, 2001), and previous knowledge. On one hand, educational robotics is a tool to support reaching outcomes, but on the other hand it also brings challenges that can cause opposite effects when handicapped motivation is developed, if the task is too complicated and pedagogical support is not provided. Another challenge is the assumption that ER supports knowledge building, forgetting about other possible outcomes that play an important role in helping students to become active learning actors. Also, challenges can be raised if ER activities are provided as non-formal educational activities that are available for a special group of students – those whose families can pay for these activities or those who are labelled as the focus group of activities (for example, 'children at risk', 'Muslim girls', etc.). Children don't want to be labelled. If ER activities are provided at a time when the school bus can't take students home, this again provides the possibility to participate for those who live close to the educational setting or whose families can take them home by car. Students who are labelled can feel satisfied and encouraged inside such groups, but they can feel excluded from the compulsory education environment because of feeling 'labelled'. This risk can be observed not only in countries of low gross private domestic investment (GPDI), where formally the possibility is provided, but hidden factors are not met.

There are some examples how to evaluate outcomes while using ER in learning context:

I Questionnaire for students (before activities)

Hello! You are going to learn how to work with Robots! Congratulations! It is fun! Before start learning, can you answer some questions? Your responses are anonymous!

1. I am:

☐ boy ☐ girl

I am ______years old (your age)

2. Learning and achievements Please evaluate these statements in scale from 1-5, where 1– completely disagree, 2 - rarely agree, 3 - sometimes agree, 4 – mostly agree, 5 – completely agree	
3.1. Learning is fun	
3.2. My achievements depend on my learning	
3.3. I do all the homeworks	
3.4. I like to cooperate with my classmates in lessons	
3.5. I like to work individually to do assignments	
3.6. I like to do extra assignments	
3.7. I like when there are different activities in lessons	
3.8. I like when I can do something active in lessons	
3.9. I like to solve learning problems by myself	
3.10. I like to look for extra information needed for learning	
3. If you miss lessons it happens because Please evaluate these statements in scale from 1-5, where 1 – always , 2 – often, 3 – sometimes, 4 – rarely, 5 – never	
4.1. I was sick or had an appointment to doctor	
4.2. I had to participate in another activity – sports, art, etc.	
4.3. I had to help my parents	
4.4. It was unpredictable situation	
4.5. I had to work	

4.6. I had to babysit my sister/brother	
4.7. I did not want to go to school	
4.8. I overslept	
4.9. I did not want to meet my classmates	
4.10. I do not like learning	

5. **Please write here three learning subjects which you like the most**

5.1.____

5.2.____

5.3.____

6. **Please write here the three learning subjects which you don't like the most**

6.1.--------------------____

6.2.____

6.3.____

II Questionnaire for students (after activities)

You had a wonderful opportunity to learn how to work with Robotics. We hope you enjoyed that! Can you answer some questions about your experience? Your responses are anonymous!

1. I am:

☐ boy ☐ girl

2. I am ______years old (your age)

3. Which Robotics activities did you like most? Please write at least three of them

____

____

____

____

4. Which Robotics activities were most challenging? Please write them

____

____

____

____

5. Learning with robots Please evaluate these statements in scale from 1-5, where 1– completely disagree, 2 - rarely agree, 3 - sometimes agree, 4 – mostly agree, 5 – completely agree	
5.1. Learning by using robots was fun	
5.2. I have learned how to program robots	
5.3. I liked to work in groups to do assignments with robots	
5.4. I liked to make calculations for programming	
5.5. I can use this knowledge in other activities	
5.6. I liked to solve problems with programming by myself	
5.7. I liked that others helped me to solve problems with programming	
5.8. I liked to look for extra information needed for using robots	
5.9. Other outcome (please write it)	
6. Activities with robots helped me to improve my: Please evaluate these statements in scale from 1-5, where 1– completely disagree, 2 – rarely agree, 3 - somehow agree, 4 – mostly agree, 5 – completely agree	
6.1. understanding of Math	
6.2. understanding of Physics	
6.3. understanding of Informatics and technologies	

6.4 attitude to learning	
6.5. cooperation skills with my classmates	
6.6. cooperation skills with teachers	
6.7. other outcome (please write it)	

7. Please write here three learning subjects where your learning outcomes improved

7.1.____

7.2.____

7.3.____

III Structured evaluation questionnaire for teachers (to be filled after activities)

Dear Teacher,

Please assess the changes in students' attitude who have participated in activities. Use the same code for students, which was used before activities. This survey is very important. It will take approximately 5 minutes to fill the questionnaire. Thank you in advance for your time.

Student ____ (code)

Gender_____

Subject/s you teach ____

Attitude to learning (statements are the same as in the first questionnaire, but evaluation is based on changes in students' attitude) Please evaluate these statements about the student's attitude in a scale from 1-5, where: 1 – no changes at all, 2 – some signs of improvement observed occasionally/rarely, 3 – some signs of improvement observed sometimes, 4 – signs of improvement observed in most situations, 5 – strong improvement observed in all situations	
Preparation of homeworks	
Cooperation with teachers in a positive way	
Cooperation with classmates during lessons in a positive way	
Readiness for work in lessons	
Understanding of the connection between learning and achievements	
Readiness to do extra assignments to improve achievements	
Following of the behavioral rules in the classroom	
Readiness to join out of class/school activities together with other classmates	
Readiness to join activities led by other classmates	
Readiness to reach learning aims	

Motivation (statements are the same as in the first questionnaire, but evaluation is based on changes in students' motivation) Please evaluate these statements about the student's motivation in a scale from 1-5, where: 1 – no changes at all, 2 – some signs of improvement observed occasionally/rarely, 3 – some signs of improvement observed sometimes, 4 – signs of improvement observed in most situations, 5 – strong improvement observed in all situations	
Motivation to learn the subject you teach	
Motivation to understand his/her mistakes to correct them	
Motivation to improve achievements	
Motivation to overcome difficulties in learning	
Readiness to works hard to achieve the aim	
Observed problems (statements are the same as in the first questionnaire, but evaluation is based on changes in students' behaviour) Please evaluate these statements about the student's behaviour in a scale from 1-5, where: 1– no changes at all, 2 – some signs of positive improvement observed occasionally/rarely, 3 – some signs of positive improvement observed sometimes, 4 – signs of positive improvement observed in most situations, 5 – strong positive improvement observed in all situations	
Being late for the beginning of lessons	
Problematic behaviour during recess (break)	

Aggressiveness to other students	
Aggressiveness to teachers	
Using rude language with classmates	
Using rude language with teachers	
Rejection to do assignments during the lessons	
Aggressive reaction in situation of conflict	
Problem solving skills Please evaluate these statements about the student in a scale from 1-5, where: 1– never, 2 – rarely, 3 – sometimes, 4 – often, 5 – always	
Solves the learning problems by himself/herself	
Asks for help from teachers	
Solves the conflicts in a calm way	

Thank you!

IV Structured observation protocol to be filled by teachers (to be filled during activities)

Protocol of observation

Teacher___________________________

Legend: 0 – can't be observed; 1 – low level; 2 – can be observed almost in all situations; 3 – can be observed during all Project; 4 – does more than expected

Code of the student Criteria									
Cooperates with other members of the group during activities in a positive way									
Is ready to do extra assignments to improve achievements									
Obeys behavioral rules during the projects									
Knows the aim of the task and how to achieve it									
Solves the faced problems by himself/herself									
Asks for help from teachers									
Solves problem situations in a calm way									
Is motivated to overcome difficulties in doing tasks									
Is motivated to understand mistakes to correct them									
Do assignments during the robotics classes									
Participates in group work									
Helps to peers in problem solving									

10.Useful information (links to resources)

- https://projects.raspberrypi.org/en/projects/robot-antenna
- https://d-clicsnumeriques.org/resssources/ - Parcours “Robotique”
- https://www.microsoft.com/en-us/education/education-workshop/brain-impact-simulator.aspx
- https://www.poppy-project.org/en/robots/poppy-ergo-jr
- https://drive.google.com/uc?export=download&id=0B2jV8VX-lQHwTUxXZjF3OGxHVGM
- https://www.generationrobots.com/
- https://github.com/pollen-robotics/rosa
- https://www.softbankrobotics.com/
- http://www.naochallenge.it/

References

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Harlow (UK): Longman.

Arfé, B., Vardanega, T., Ronconi, R. (2020). The effects of coding on children's planning and inhibition skills. Computers & Education, Volume 148. ISSN 0360-1315. https://doi.org/10.1016/j.compedu.2020.103807.

Akermann, E. K. (2001). *Piaget’s Constructivism, Papert’s Constructionism: What's the Difference*. (MIT Media Lab) Retrieved November 15, 2018, from Future Learning Group: http://learning.media.mit.edu/content/publications/EA.Piaget%20_%20Papert.pdf

Alimisis, D. (2013). Educational robotics: Open questions and new challenges. Themes in Science & Technology Education, Vol 6, pp 63-71.

Bandura, A. (1986). Social foundations of thought and action : a social cognitive theory / Albert Bandura. Englewood Cliffs, N.J: Prentice-Hall, 1986. xiii, 617 pp.

Bers, M.U., González-González, C. & Armas–Torres, M.B. (2019). Coding as a playground: Promoting positive learning experiences in childhood classrooms. Computers & Education, 138(1), 130-145. Elsevier Ltd. Retrieved March 18, 2021 from https://www.learntechlib.org/p/209930/

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals*. *Handbook I: Cognitive Domain.* New York: David McKay Company.

Catlin, D. (2019). Beyond Coding: Back to the Future with Education Robots. In L. Daniela (Ed.), *Smart Learning with Educational Robotics: Using Robots to Scaffold Learning Outcomes* (pp. 1-44). Cham, Switzerland: Springer Nature Switzerland AG

Gagné, R. M., Briggs, L. J., & Wager, W. W. (1992). Principles of instructional design (4th ed.). Forth Worth, TX: Harcourt Brace Jovanovich College Publishers.

Keller, J., M. (2010). *Motivational Design for Learning and Performance: The ARCS Model Approach.* London: Springer. ISBN 978-1-4419-1250-3

Migdley, C., & Urdan, T. (2001). Academic self-handicapping and performance goals: A further examination. Contemporary Educational Psychology, 26(1), 61–75. https://doi.org/10.1006/ceps.2000.1041.

Papert, S. (1980). Mindstorms: children, computers, and powerful ideas. Basic Books, Inc.

Romero, M., Lepage, A., & Lille, B. (2017). Computational thinking development through creative programming in higher education. International Journal of Educational Technology in Higher Education, 14(1), 42. https://doi.org/10.1186/s41239-017-0080-z

Scaradozzi, D., Screpanti, L., Cesaretti, L. (2019) Towards a definition of educational robotics: a classification of tools, experiences and assessments. In: Daniela, L. (Ed.),Smart learning with educational robotics – using robots to scaffold learning outcomes (pp 63-92), Cham, Switzerland: Springer Nature Switzerland AG

Vygotsky, L. (1987). Zone of proximal development. Mind in Society The Development of Higher Psychological Processes, 157, 5291 SRC.

Waterson, A. (2015). Lego mindstorms: A history of educational robots. Retrieved November 22, 2018, from Hack Education: http://hackeducation.com/2015/04/10/mindstorms

Wing, J. M. (2006). Computational thinking. Communications of the ACM, 49(3), 33–35.

[1] https://en.wikipedia.org/wiki/Ohm%27s_law

[2] https://en.wikipedia.org/wiki/Kirchhoff%27s_circuit_laws

ROBOSCIENTISTS PROJECT
Motivating secondary school students towards STEM careers through robotic artefact making

Erasmus+ KA2 2018-1PL01-KA201-051129

Creators

Linda Daniela (University of Latvia)
Arta Rudolfa (University of Latvia)

Declaration

This report has been prepared in the context of the ROBOSCIENTISTS project. Where other published and unpublished source materials have been used, these have been acknowledged.

Copyright

Funding Disclaimer

This project has been funded with support from the European Commission. This communication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.