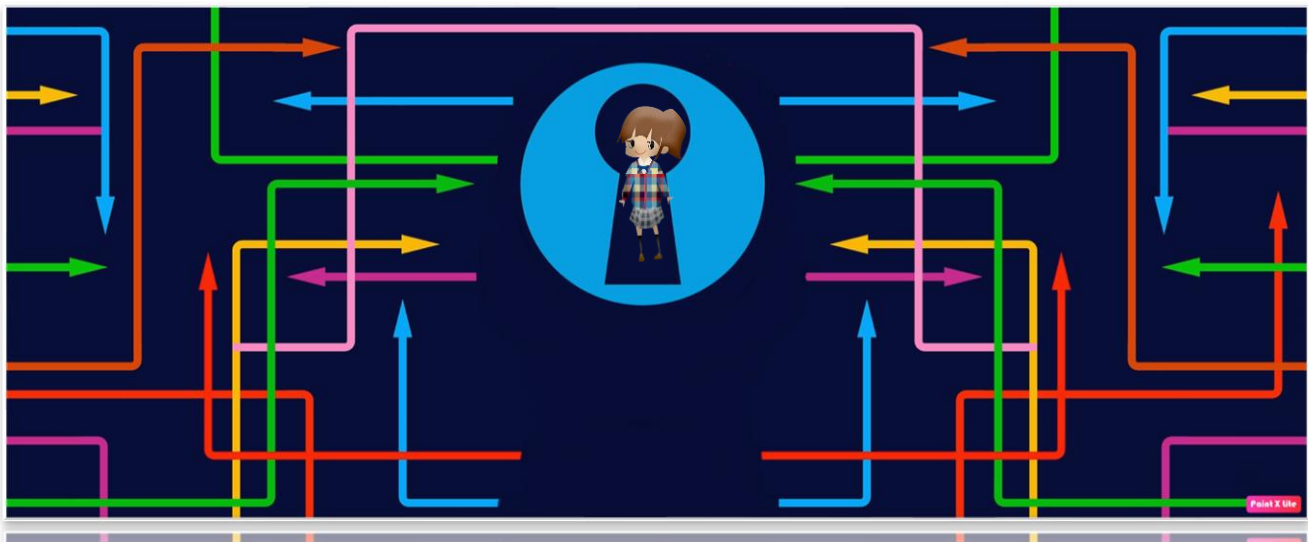




## ALGORITHMIC THINKING SKILLS THROUGH PLAY-BASED LEARNING FOR FUTURE'S CODE LITERATES

2020-1-TR01-KA203-092333



## INTEGRATION OF ALGORITHMIC THINKING SKILLS INTO PRESCHOOL EDUCATION

### BASIC PRINCIPLES

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# INTRODUCTION

This report is the first deliverable, briefing about the issues to meet the training needs of the preschool teaching undergraduates who will integrate algorithmic thinking skills into different learning areas in preschools and prepared in the scope of The EU funded Erasmus+ Key Action 2 (203) – The Strategic Partnership project entitled "Algorithmic Thinking Skills through Play-Based Learning for Future's Code Literates – ALGOLITTLE".

It is a compilation of the literature reviews undertaken to identify the training needs of future preschool teachers related to the delivery of coding education in preschools.

The report features 6 chapters, each contributing to the aspect of identifying

1. The content of the training for "Integration of Algorithmic Thinking Skills into Preschool Education"
2. The work with respect to engagement with instructors (training providers), other beneficiaries and also STEM researchers
3. The grounds and principles of the evaluation of the training activities

**Chapter 1** is the introduction, giving information about the document along with a brief explanation about what the knowledge paper addresses, presenting the project objectives, expected results and impacts, and introducing the content of each chapter.

**Chapter 2** provides brief explanations about the algorithmic thinking skills including an overview of the skills that can be taught in preschools and information about how to use play-based learning to facilitate the learning processes.

**Chapter 3** discusses the appropriate learning areas to integrate algorithmic thinking skills into preschool education.

**Chapter 4** identifies the scope and the future benefits of the integration of algorithmic thinking skills into preschool education.

**Chapter 5** provides information about the current educational practices related to fostering algorithmic thinking skills and teaching coding in preschools.

**Chapter 6** includes a conclusion, which provides suggestions about how to integrate algorithmic thinking skills into preschool education and discusses the most prominent training needs revealed as a result of the literature reviews both in general and on the basis of the practices in the partner countries.

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## Introduction to the Project

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ALGO-LITTLE is the EU funded project in search of ways to integrate algorithmic thinking skills into preschool education for the purpose of growing future's code literates starting from the earliest ages. As every work field and sector moves on to online, also considering the accelerated process in the COVID-19 pandemic, education also has been digitalized at an extraordinary speed and the developments are promising a more globally digitized systems in the future. We need to catch up with the innovations and assist our new generations to get ready for the job requirements in terms of digital competencies and skills.

For this reason, ALGO-LITTLE will develop a course programme and teaching materials to give training to the preschool teaching undergraduates in the partner universities to equip them with the new demands of the contemporary world and assist their students to grow as equipped persons who can meet the requirements of the professions they will have.

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## Aims & Objectives

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We primarily aim at preparing a course programme and teaching materials to teach preschool teaching undergraduates how to reflect the algorithmic thinking skills in all areas of preschool education and integrate it into the teaching of music, art, mathematics, drama, science, social sciences, social and emotional learning, play, sports, and language development, which are addressed in preschool education.

As ALGO-LITTLE, we define preschool education as education for children age 1 to 6 years. Several EU curriculums divide two age groups/periods. First age period is from 1 to 3 years old children and second age period is from 4 to 6 years old children. In further text, we will use these definitions' consensus when referring to specific skills, abilities, and competencies of children in preschool education.

Our other objectives are;

- Closing skills gaps in ICT oriented teaching/learning activities for immediate impact on contemporary teaching skills of preschool teaching undergraduates
- Increasing the acquisition of knowledge and skills of preschool teaching undergraduates related to employing algorithmic thinking skills through play-based learning as an innovative teaching approach
- Upskilling the lecturers of the partner universities related to the integration of algorithmic thinking skills into all subject areas focused in preschool education.

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## Expected Impacts of the Project

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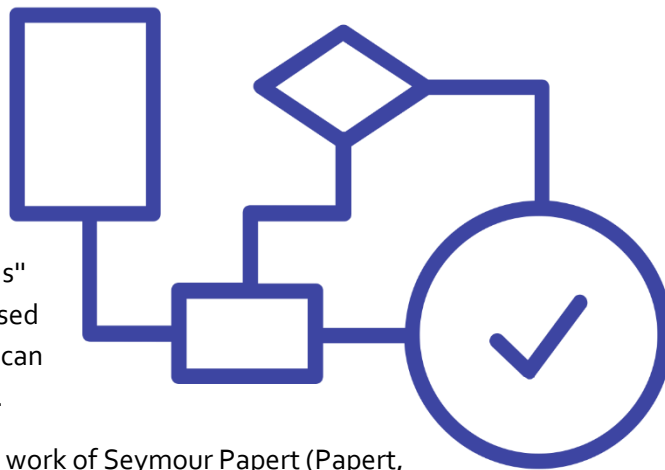
The project practice will directly impact on the preschool teaching undergraduates' upskilling in the teaching of different subject areas. They will learn how to support children to see the happenings from different angles. Because a situation can include many different scenarios. Let's take "the vacation" as an example. What is our purpose on a vacation changes the whole path we follow. Whether you want to see many places or only one place in one week will draw the frame of your vacation in utterly different ways. Therefore, the creation of different algorithms (small steps) which we will follow will lead us to totally different experiences. Undergraduates will also learn how to support children to create algorithms, to apply them and see if they can reach the objective or not. Undergraduates will also learn how to support children to check their steps, to see the problematic ones and correct them.

Programming, coding that is namely all computing technologies are the magnificent results of the reasoning of the human brain. Human being not only develops his/her new generations but also machines. This means if we can improve the reasoning of children, we will be able to equip them with the necessary skills to create codes (consist of algorithms), to solve problems, to see the happenings from different aspects and to come up with functional ways to achieve their objectives.

# ALGORITHMIC THINKING

## What is Algorithmic Thinking?

Algorithmic thinking stems from the concept of an algorithm, which refers to solving a problem by developing a set of steps taken in a sequence to achieve the desired outcome (Katai, 2014). So, let's start to define an algorithm which is "a method used to solve a problem consisting of fully defined commands" (Futschek, 2006). Algorithmic thinking is a frequently used term as one of the most important competencies that can be obtained with informatics education (Snyder, 2000).



Algorithmic Thinking stems back to the constructionist work of Seymour Papert (Papert, 1980, 1991) and was first coined as a term in a seminal article by Wing (2006). She explained that Algorithmic Thinking entails "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (Wing, 2006, p.33).

The most cited definition of Algorithmic Thinking (or its closer version, the Computational Thinking) comes from Cuny, Snyder, and Wing (2010), noting that Algorithmic Thinking is a thinking process where "... solutions are represented in a form that can be effectively carried out by an information-processing agent" (Wing, 2010, p.1)

This relates not only to well-structured problems, but also ill-structured problems (i.e., complicated real-life problems whose solutions are neither definite nor measurable).

Algorithmic thinking was also defined as "the ability to understand, execute, evaluate, and create computational procedures" (Lamagna, 2015).

Other researchers have come up with their own definitions relative to their research areas. For instance, Barretal (2011) concluded that in K-12, Algorithmic Thinking involves problem-solving skills and particular dispositions, such as confidence and persistence, when confronting particular problems.

Berland and Wilensky (2015) defined Algorithmic Thinking as "the ability to think with the computer-as-tool" (p.630) and suggested using "computational perspectives" as an alternative to "computational thinking" to emphasize that Algorithmic Thinking can be constrained by contexts.

Additionally, Algorithmic Thinking has been defined as "... (the skill of) students using computers to model their ideas and develop programs" (Israel, Pearson, Tapia, Wherfel, & Reese, 2015, p.264), explicitly linking Algorithmic Thinking to programming skills.

Sadykova & Il'bahtin (2020), presented a table including different definitions of algorithmic thinking made by several academicians as follows.

No.	Author	Definition
1	S.D. Yazvinskaya	<i>as an art and the ability to think, plan, foresee different circumstances</i>
2	A.P. Ershov, M.P. Lapchik, I.G. Semakin, Yu.A. Pervin	<i>this is a special way of thinking based on the technology of step-by-step solution of the problem</i>
3	A.G. Gein	<i>the creation of the subject's system of mental modes of action, techniques, methods, mental strategies</i>
4	Ya.I. Grudenov	<i>formation of the ability to make the best possible decisions</i>
5	G.A. Zharkova, L.N. Polyakova	<i>ability to break tasks into consecutive interconnected blocks</i>
6	A.P. Ershov, G.A. Zvenigorodskij, Yu.A. Pervin	<i>ability to plan the structure of actions required to achieve a goal with a fixed set of tools</i>
7	A.G. Kushnirenko, G.V. Lebedev	<i>the method and the way that are necessary for the transition from direct control to software, from the ability to make to the ability to write the algorithm</i>
8	A. I. Gazejkina, I.N. Slinkina.	<i>cognitive process characterized by the presence of a clear, appropriate (or rational) sequence of mental processes committed with the inherent detail and optimization of enlarged blocks, conscious consolidation of the process of obtaining the final result, presented in a formalized form in the language of the performer with the accepted semantic and syntactic rules.</i>

Algorithms encompass the whole range of concepts dealing with well-defined processes, including the structure of data that is being acted upon as well as the structure of the sequence of operations being performed (Knuth, 1985).

Algorithmic thinking is a pool of skills linked to building and understanding algorithms:

- the ability to analyze given issues the ability to pinpoint a problem
- the ability to find basic actions suitable for a given problem
- the ability to create an accurate algorithm to a specific problem using basic actions
- the ability to think of all possible special and normal situations of a problem
- the ability to increase the efficiency of an algorithm (Futschek, 2006)

Components of Algorithmic Thinking, Wing (2006) argued that Algorithmic Thinking does not mean to think like a computer; but rather to engage in five cognitive processes with the goal of solving problems efficiently and creatively.

These include:

1. Problem reformulation: Reframe a problem into a solvable and familiar one.
2. Recursion: Construct a system incrementally based on preceding information.
3. Problem decomposition: Break the problem down into manageable units.
4. Abstraction: Model the core aspects of complex problems or systems.
5. Systematic testing: Take purposeful actions to derive solution

As described above, Algorithmic Thinking definitions vary in their operationalization of Algorithmic Thinking certain studies, and are not particularly generalizable (e.g., Berland & Wilensky, 2015; Ioannidou, Bennett, Repenning, Koh, & Basawapatna, 2011; Israel et al., 2015). The definition of Algorithmic Thinking is evolving as researchers begin to aggregate knowledge about the concept.

To sum up, Algorithmic Thinking represents a way of solving a problem using a series of steps that lead to a solution. It is suitable not only for solving problems by computers, but also without computers in various situations of everyday life. The basic approach that develops problem-solving and programming skills is Computational Thinking. Computational thinking involves algorithmic thinking that is important for shaping problems. Logical thinking, evaluation, decomposition, abstraction, generalization, and other computer thinking skills previously analyze the problem (Project GLAT). The development of algorithmic thinking skills encourages the development of other skills such as creativity, logical thinking, analogy, decision-making and the like. It is important to develop algorithmic thinking skills from an early age so that they can be applied both in learning situations and in solving problems in everyday life situations.



## Algorithmic Thinking Skills

Algorithmic thinking skills include some of the computer thinking skills but primarily relate to identifying problems, defining possible solutions, and analyzing and selecting the best solution. Of course, solving the problem itself requires much more skills than the above, however we could say that the main ones in the approach that uses algorithmic thinking are perceiving a problem, generating solutions, and solving a problem.

Problem Solving involves analytical skills such as analysis and logical reasoning as well as creative skills such as creative thinking, initiative, and persistence.

### *Components of Algorithmic Thinking*

Futschek offers this example for actions involving Algorithmic Thinking.

*Paths in Mazes:* Finding a path in a maze (labyrinth) is a classical task and is not trivial. Usual tasks are:

- Find a path out of a maze,
- Find a path through a maze, or
- Find a path to a specific position inside a maze

1: analyzing the problem.

2: Decide at each crossing which corridor to go and the applied decision strategies.

3. Trying to *model* the Maze.

4. Defining the basic actions that can be performed when a node (crossing) is reached by an edge:

- action 1. Query: Is the goal reached?
- action 2. Determine the number of edges (corridors) that leave this node.
- (If this number is 0, then a dead end is reached)
- action 3. Follow the its edge and go to the connected node (crossing).
- (The 1st edge is called the leftmost edge)
- action 4. (Turn around 180 degrees and) go back to previous node,
- following edge e.

Using these 4 basic actions, it is possible to formulate the algorithms of our case.

Wing (2006) argues that Algorithmic Thinking does not mean to think like a computer; but rather to engage in five cognitive processes with the goal of solving problems efficiently and creatively. These include: Problem reformulation:

- Reframe a problem into a solvable and familiar one.
- Recursion: Construct a system incrementally based on preceding information.

- Problem decomposition: Break the problem down into manageable units.
- Abstraction: Model the core aspects of complex problems or systems.
- Systematic testing: Take purposeful actions to derive solution.

Abstraction is the main element undergirding AT (Wing, 2008), where people glean relevant information (and discard irrelevant data) from complex systems to generate patterns and find commonalities among different representations (Wing, 2010).

Abstraction has layers, so one must define each layer and clarify the relationships between layers.

This involves:

- (a) Abstraction in each layer,
- (b) Abstraction as a whole,
- (c) interconnection among layers. For instance, defining an algorithm is one kind of abstraction - the “abstraction of a step-by-step procedure for taking input and producing some desired output” (Wing, 2008).



First introduction to algorithms can be learned at a problem-oriented level independent from any programming language. A wide series of informatics relevant topics can be addressed and learned by solving interesting and encouraging problems.

A visualization of the algorithms in form of a program-tool or of an activity play performed by the students themselves can be very helpful. Beginners like to play with algorithms while feeding them with different input values to get an impression how the algorithms work and what problems arise. (e.g. non-termination or combinatorial explosion)

To improve or modify algorithms, abstract models and precise definitions of properties are necessary.

## 1- Perceiving a Problem

Learning by problem-solving is in line with scientific research, even for young children (Mezak and Pejic Papak, 2019):

- Defining a problem situation
- Formulating of the problem: finding an algorithm of the solution
- Hypothesis setting: selection of methods and forms of research
- Solving problems: verifying the hypothesis
- Analysis of research results that are followed by a conclusion and an application to new problem situations

When considering young learners, collaborative problem solving is recommended. Problem solving competency means engaging students in solving a problem using different strategies, from multiple perspectives and with diverse modalities. This process considers structured and guided approaches for young learners. Novice learners need guidance to develop their problem-solving skills, as well as self-directed learning skills.

The principles of Inquiry Based Learning can be used for better perception of a problem. Teacher/educator can guide the inquiry by asking questions about the learning topic. Research questions are presented using conversation as a teaching method. Motivation is very important for solving the problem, especially when this is a task for young children. Motivation can start with so-called “spark” – a stimulus or challenge provided by the educator at the beginning of the activity. Children take part in the activity by responding to the “spark”.

It is important that children understand what the problem is and what is expected from them to do.

## 2- Generating Solutions

Defining possible solutions is also an algorithm so it should be observed in steps such as realising the concepts, using analogies to compare, creative thinking and planning the steps that will lead to solution. The best method for generating solutions is brainstorming and it should be involved in all aforementioned steps. The participants, that is children, concentrate on the problem and then try to come up with as many, as radical solutions as possible. Teachers/educators should intentionally encourage children to come up with as wide and unusual ideas as possible, where speed is an important factor, since dynamism is one of the main characteristics of a brainstorming.

### A. Realising the concepts

Meyer and Land define basic, fundamental concepts for a particular area being studied as concepts that children must fully understand to understand the problem they will be dealing with. “Such threshold concepts share five key characteristics: they are irreversible, integrative, bounded, initially troublesome, and transformative.”

If children are well familiar with the concepts that make up a problem, they can also understand the reasons why to solve the problem. Ability to interpret the problem with their own words integrates all previous knowledge into understanding the problem in a different way. Children evoke their prior knowledge, particularly the failure to solve the problem. After the teacher helps them solve misconceptions, children can determine and assemble new knowledge about the problem.

### B. Using analogies to compare

When children encounter some new and unknown problems to solve, they unconsciously use a deductive way of learning based on constructivist theory. Children use the skills of synthesis, interpretation, and evaluation of existing knowledge while the teacher acts as a facilitator and moderator who encourages children to create new knowledge using analogies and comparisons. Children are also encouraged to give examples of similar problems they know about and to make comparisons together.

### C. Creative thinking

According to Sternberg and Lubart (1999) creativity is the ability to produce work that is novel (i.e. original) and appropriate (i.e. useful, adaptive concerning task constraints), further science writes “A creative idea is one that is both original and appropriate for the situation in which it occurs” (Martindale 1999).

According to Guilford (1950), two models of thought could be considered: convergent and divergent. The divergent model could be associated with creative thinking. The divergent thinking is characterized by some elements:

- Fluency: competence to offer alternatives to problems
- Flexibility: ability to analyse the same issue in different ways
- Originality: the skill of creating new ideas
- Redefinition: the skill of not being influenced by what we already know
- Penetration: the ability of discovering new factors in analyzed problems
- Preparation: the ability of generating detailed information on the subject matter
- The generalizing skill of transferring this process to other problems

Resnick (2017), furthermore, shows that creativity is not only something related to arts and artists, but something that can be used by everyone and can be learned and developed. He states, according to researchers, that there exist two kinds of creativity: the "uppercase C" and the "lowercase c" creativity. The first one is the creativity as intended by Sternberg and Lubart, and related to truly new and important ideas, such as ideas coming from Nobel Prizes winners, great scientists, and artists. Then he focuses on the "lowercase creativity", he imagines that if you find a new and useful idea that is useful to you, even if it has already been found by others, you are using creativity. He took, as an example, the paperclips: the invention of the paperclips was uppercase Creativity, every time someone finds a new use of a paperclip in day life, we are talking about lowercase creativity.



Resnick, also outlines the term Creative Thinking. He simply refers to it as the way we can use creativity to find new ways to solve problems, especially day life problems. He, and his research team, the MIT Media Lab, also designed an approach the "4 P's of Creative Learning Approach", to give guidelines to teach using creativity. So intended, creative thinking totally sticks to the algorithmic thinking process, because it provides a different point of view of the problem-solving process, outlined, and discussed in the next paragraph.

### 3- Problem-Solving

According to the study "Soft skills 4 talent 2016" (Human Age Institute, 2016), the most relevant skill to Talent is Problem Solving, evaluated as the most important skills by the interviewed human resource responsible. The problem-solving skill could be outlined as "Problem-solving competence is defined as the capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious." (OECD, 2014).

As seen in the previous introductory section, algorithmic thinking is strictly related to problems, and its solving ways. Anytime we encounter a new problem we must address and solve it and using the algorithmic approach we must decompose it and to find a logical sequence of steps that can solve it.

#### A- Critical Thinking

This review about Algorithmic Thinking is based on the human concept of thought. In fact, the AT is a way, an approach, in thinking and in elaborating information and data. In every thinking approach it is important to use a critical mindset, to properly achieve our goal. In this view, critical thinking could help us in our process.

According to Elder & Paul (2007) "Critical thinking is the process of analyzing and assessing thinking with a view to improving it ... The key to the creative side of critical thinking (the actual improvement of thought) is in restructuring thinking as a result of analyzing and effectively assessing it".

According to Dewey thought (1993), we do not learn only through our experience, but we learn only when the information that we obtained has been understood, so the relation between them has been found, so we learn when we reflect on the experience. From this point of view critical thinking assume two meanings: it can directly help in addressing problems and supporting the algorithmic approach, furthermore it is also an important element of the learning approach, because we can understand concepts only when we reflect about them, so the algorithmic approach - that oblige to use a critical mind - can better support the learning.

#### B- Planning (STEPS) and Following the Steps/Ideas to Solve a Problem

Problem reformulation/decomposition refers to the skill of reformulating a difficult problem as a familiar one or breaking it down into smaller parts to make the problem easier to solve (Shute et al., 2017; Wing, 2006). This skill can reduce ambiguity and allow students to understand intended solutions more effectively. When a problem is presented as an algorithm, it is broken down into smaller parts that can be known to children and that can be solved using a set of rules (algorithms) to find a solution and a description of similar solved problems (Wing, 2006). Algorithms are basically a set of simple tasks that everyone can solve, from simple cooking recipe instructions to providing complex driving instructions. Children are most easily introduced to the concept of algorithms by using examples from their daily lives. For example, at early age children an algorithm can be described steps involved in brushing their teeth, while at an older age they could participate in sequential steps during a lab experiment

(Mezak and Pejic Papak, 2018). However, according to Shelton (2016), the development of algorithmic thinking in young children does not necessarily require the use of computers, but can also be achieved by "unplugged" methods, which are not an alternative to computer use but should be used as an auxiliary activity in understanding and solving problems. Teachers need to have a new role in the teaching process to help the child by leading the child and intervening at the appropriate time for a particular child in a context that increases task-solving abilities. This procedure is known as scaffolding, "a process by which a teacher or more knowledgeable peer assists a learner, altering the learning task so the learner can solve problems or accomplish tasks that would otherwise be out of reach." (Reiser, 2004). For example, a teacher can help a child in social play by reminding him of the rules or suggesting strategic steps if the child gets stuck (Reiser, 2004). Game Based Learning (GBL) as a learning strategy is generally very useful in young children, because preschoolers are at an age when games are particularly effective. In this period, children have difficulty learning abstract concepts and procedures, so such entertainment methods and active participation can enhance the learning process.



### C- Choosing the Best Solution

Most problem-solving skills are developed through everyday life and experience by utilizing 'Mind games' such as crosswords, puzzles, board games, etc. Some computer games may involve strategic planning to analyze and evaluate the advantages and disadvantages of different decisions or actions taken.

Children need to explore the consequences of their own solutions, try different approaches to problem solving, which encourages collaboration, sharing ideas and creating a common solution. Selecting the best solution is an iterative process by which the solving algorithm is constantly changing, upgrading, and improving. (Shute et al., 2017; Yadav et al., 2014 Wang et al., 2020).

### 4- Cooperativity

AT has usually been considered as an individual competence. However, at present, real problems are becoming increasingly complex problems in which a single person finds great difficulty in finding the solution. (Varela et al, 2019). Social competences and cooperative work are becoming more and more needed in 21st century life, we need people who can work as a team. Teamwork can lead us to better results rather than individual work. But, what do we mean about cooperative thinking? According to Missiroli et al. (2017) "cooperative thinking is the ability to describe, recognize, decompose problems and computationally solve them in teams in a socially sustainable way".

This definition is strictly related to algorithmic thinking, and generally to the learning process. In 1980 Papert wrote about the importance of social interaction in learning. Then other authors wrote about this, including Resnick (2017) who took inspiration from this, especially talking about one of the 4P's of creative learning: the p of Peers. He wrote that learning is a social process, where people share ideas, questions, answers and opinions, and the creation of a community could improve the learning process. So intended, this approach totally fits the algorithmic thinking ideas.

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## Which Algorithmic Skills can be Taught in Preschools?

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Algorithmic Thinking is directly related with computational thinking and can be used for any problematic process that requires a solution either through programming or in real life situations. The acquisition of this thinking skill can help children organise their daily activities in an appropriate manner, produce more effective solutions to the challenges they encounter and also facilitate them to become the coders of their own computer programmes.

Early childhood education algorithmic skills include abilities to learn and work according to the rules or models, children are capable to understand, use, apply and develop simple algorithms. Children are also capable of analyzing and correcting the sequence of actions to reach results, to transfer acquired methods of actions to new situations and to describe their activities to others in a clear way. Precise description of activities is possible mainly in the age 4 and above, when children are capable to verbalize their actions. Algorithmic thinking skills which can be taught in preschool also include dividing a problem into smaller parts, proceeding step by step, trying to find the most effective solution, development of logical thinking, spatial orientation, pre-literacy, pre-numeracy skills, social-emotional skills etc. (Voronina et al., 2016). Algorithmic thinking is developed by solving various problems that reflect real-life situations and questions. It is important that teachers in preschool education encourage integration of algorithmic thinking into daily teaching (Games for learning algorithmic thinking, 2017).

The study of Voronina et al. (2016) showed that preschool children who were thought of algorithmic skills showed higher level of planning activity development (in average for 69,3% in comparison to control group with only 20,3 % increased rate for the same parameter), children also demonstrated increased self-regulation, self-control and self-evaluation of their actions. They learned to transfer algorithms under teacher supervision and used algorithm skills in different types of their activities, they mastered skills of team work, effectively cooperated in pairs and groups to achieve desired results and were able to ask questions independently and reflect their actions in the process of algorithmic activity.

Stolyar (1988) defines three types of algorithms which are appropriate for preschool education:

1. The linear algorithm is a sequence of actions carried out in strict order and only once.
2. The branching algorithm is characterized by a certain condition that should be checked and if it is true a sequence of steps is performed, if not another sequence of steps is performed
3. The cyclic algorithm includes actions that should be repeated several times until a certain condition is met.

### Linear Algorithm

The linear algorithm (sequences) is appropriate for children age group 1 to 3. Teaching of linear algorithms in preschool education contains development of children's ability to use linear algorithms for the solution of educational problems. Teacher presents the problem and the solution, with explaining the steps which are necessary to solve the problem. For example, the problem can be how to make a snowman from three paper circles, which differ by size. Teacher can



explain how to make a snowman with putting the largest circle on the bottom and the other two above in vertical line by size. Children repeat the algorithm and make a snowman. After this exercise, children can be encouraged to transfer this knowledge to the natural environment with real snow, if possible. Research indicates that preschool children can construct sequences in the linear direction and within a familiar context, but they cannot necessarily discuss the logic or cause and effect related to those sequences (Kazakoff, Sullivan, & Bers, 2013).

In a coding activity with Lego® Education WeDo 2.0 [2] basic set (with the children at the age of 4-5), it was observed that children constructed animal robots by following the instructions and designed an activity to move them on different routes (Strnad, 2018). This showed that children could create an algorithm and then observed how it worked. During the activities, it was observed that children relied on their previous knowledge about ordinal numbers and helped the characters (these characters represented the programmable robots) to reach their destinations. Seen that they mostly designated the routes through trial and error, and they observed what happened when they designated the routes differently. From this point of view, we can say that children who are older than 3 years old will accommodate themselves to creating sequences by trial and error, then observe how these sequences work and troubleshoot when the robots can't reach their destinations.

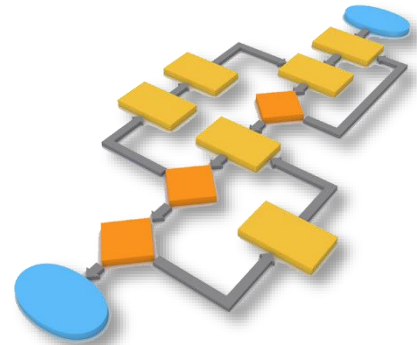
### Branching Algorithm

The branching algorithm (selections) is appropriate for children age 3 and above. Teaching of branching algorithms in preschool education includes development of initial skills to create algorithms. Teachers can use various games and exercises for children to create or continue algorithms (e.g. make a bear come to honey, without distracting the bees in the computer game, fill in the missing steps in a board game or fairy tale, arrange the cards in correct order as learning of sequencing).

### Cyclic Algorithm

The cyclic algorithm (iterations, loops) can be taught in combination with other algorithms, where children are capable of consolidating algorithm skills and transferring the algorithms to various educational activities (appropriate for age 4 and above). Teachers can use a story and show story algorithm in various cycles. For example, what would happen if the Red Riding Hood would have a mobile phone or children guess which part of the process/story is important and are asked to perform the sequence of actions according to specific rules or they are able to transfer their knowledge to specific other domains.

Preschool children can break down a large task into a series of smaller steps (Sullivan, Bers, Mihm, 2017). In a research activity, children were asked to prepare lunches, each one of all including two sandwiches, two carrots and four apples. Children could manage to sort the food as sandwiches, carrots, and apples at first and then prepared the lunches. At this stage the scaffolding of the teacher played an important role to help children see how to follow the steps (Lavigne, Lewis-Presser & Rosenfeld, 2020). Preschool children can use repeat blocks to achieve a goal instead of scanning many blocks at every turn (Bers, 2018). If a route has repeating steps and turns these can be grouped as modules and be coded differently. Children can understand simple modularity (two or three steps) and while designating the route, they can break down the route into small steps including small repeat routes.



## Other Algorithmic Thinking Skills

A research activity carried out with the robot KIBO showed that children at the age of 4-7 could practice sequencing, logical reasoning, and problem-solving skills along with social skills such as collaboration and communication through these tangible robotic kits (Kazakoff, Sullivan & Bers, 2013). Therefore, starting to foster children's algorithmic thinking skills at earlier ages will contribute to both their daily life and computational skills.

If children gain awareness of the nature of algorithmic thinking (or how they use the stages of a problem-solving process) such as realizing the problem situation, dividing it into small steps, and realizing the flow of the process through playing and using real objects, they can transfer their knowledge and skills into virtual environments that need more abstract thinking in the future. Creating the algorithm before coding activities and employing algorithmic thinking through tangible objects will facilitate the transition to computer programming for children (Futschek & Moschitz, 2011).

In addition, within algorithmic thinking skills children can develop several other competences (Voronina et al., 2016). First, procedural thinking, which includes perceiving and understanding of properties, types, and ways of algorithms. Second, personal competencies and competencies of learning to learn, which include development of awareness of how important is gaining new knowledge and learning. Third, regulatory competences, which enables children to monitor, regulate and self-correct their activities and enable them to make plans. And fourth, communicative competences which include development of communication skills in all three domains: receptive, expressive and social communication (Illinois Early Learning Guidelines, 2015), interactions with adults and peers in the process of algorithmic activity. Those are life-long learning competences, crucial for development of skills mentioned above (Nottingham and Nottingham, 2019).

When it comes to debugging, some research indicates that while young children are experimenters willing to try new solutions, they often cannot gather relevant data or use systematic processes that address a particular problem (Bers, 2010). Rather than being systematic, they tend to use trial and error to fix problems as soon as they notice them. They also tend to judge the success of a solution through observation rather than reasoning. Therefore, we can say that they can see the dysfunctional action in a process, when they try it. They can try to fix the problems caused by these dysfunctions through concrete applications rather than abstract reasoning.

In a study carried out to compare the perceptions of preschool and primary school children in relation to programming concepts, preschool children went through a three-fold process including a- a floor game consisted of following algorithms by using real objects and bodies (to represent robots), b- a replication of the floor game into a board game, and c- programming of N6 robot in a computer. In the third stage, children learned how to programme the robot to avoid objects using conditionals and learned a loop (cyclic algorithm). While doing this, children needed to practice many times to move the robot with only two lines of code (Martinez, Gomez & Benotti, 2015)

Research shows that during the coding activities, children largely rely on trial and error to experiment with what will happen when steps are placed in different locations (Lavigne et al, 2020). Therefore, while planning the unplugged or plugged coding activities, children should be allowed to make several trials also by considering their attention span.

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## Integration of Algorithmic Thinking Skills into Preschool Teaching through Play-Based Learning

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Play is a meaningful activity for children in preschool education and one of their basic rights. Learning occurs during play in multiple ways and children could gain a lot from supportive teachers or other adults allowing them space, time, and interaction to develop their play activities. Play is valuable on its own right as a meaningful socio-cultural activity and not just because of its relation to learning (Hännikäinen, Singer and Oers, 2013). It is important to distinguish between activities which are play-based and adult-initiated, with skill-like tasks and free play, and to distinguish between different forms on the continuum between free play and no play when we plan to integrate algorithmic thinking skills to play. For clarification of the concepts Weisberg et al. (2013) suggest the term “guided play”, which is a type of play prepared for children and usually with defined learning outcomes, on the continuum between free play and direct instruction. It consists of adults structuring the play environment but leaving control to the children within the environment (Weisberg et al., 2015). Algorithmic thinking skills can be developed on the whole continuum between free play and highly structured play-based learning (PlayBL). Differences can be in the amount of adult initiative, instructional design, how well are defined learning outcomes, in the number of skill-like tasks and type of algorithmic thinking skills, which are developed through play.

Important holistic issues in play pedagogy are freedom, choice, participation, and inclusion. Play and learning in context are strongly related. Playful learning or use of play for learning is different to play initiated and controlled by children as players, although teachers might integrate PlayBL and algorithmic thinking in that kind of play too. Teachers and children should learn to use play as the source, context and medium for children’s learning and development (Hakkarainen et al., 2013). When teachers integrate algorithmic thinking skills in teaching through PlayBL they should keep in mind holistic perspective of children’s development and avoid the instrumentalization and regulation of play (Hännikäinen, Singer and Oers, 2013).

PlayBL is learning through games or play with defined specific learning outcomes. PlayBL in preschool education motivates children to engage with educational learning material in a playful and dynamic way. The PlayBL environment in preschool education should support active learning with exploration, problem-solving, inclusive access to PlayBL for all groups of children (e.g. children with special needs, immigrant children, minorities) and clear introduction to play activities for all. PlayBL might be more time consuming than traditional learning. Play is usually not a stand-alone activity but is part of the learning process (Games for learning algorithmic thinking, 2017).



PlayBL in preschool education should include playful learning, socializing with peers or adults, active learning, exploration, development of communication skills and self-talk, overcoming mental and physical challenges, learning of new skills, consolidation of knowledge, having fun and relaxation. Key aspects for play-based approaches in early childhood education are: a) the content needs to be part of the play or game, b) the content

of play or game needs to be presented in a clear way understandable to children, c) play or game should be essential for further learning and d) play or games needs to be appropriate for the individual learning needs or can be adapted to individual needs of the child (Gasteiger et al., 2015).

Teacher in early childhood education should primarily use unplugged activities for simulating algorithmic thinking through play, games and puzzles without the use of computer or other digital technologies, as suggest national curriculums for early childhood education in several countries (e. g. National curriculum guidelines on early childhood education and care in Finland, 2004; Developmentally appropriate practice guidelines for practice; NAEC, 2009). Digital technologies include multiple desktop and mobile technologies, digital toys and use of the internet which operates as a platform for children's consumption of digital media (O'Hara, 2011; Gutnick et al., 2011). However, there is consequent need for young children to develop new skills in reading, navigating and participating in highly digitally-mediated environments (Bittman et al., 2011) and preschool education should be well equipped to support children's learning of algorithmic skills in digital environment, with respect of pedagogical perspectives.

In play, a child always behaves beyond average age, above daily behaviour. In play, as though, (children) were a head taller than themselves.

Lev Vygotsky



# LEARNING AREAS FOR ALGORITHMIC THINKING

## Beginning to Think Algorithmically

Despite some differences between the participating countries on the age at which children enter primary school, there is a uniformity of teaching methodology that allows for common planning.

In primary school the focus is on mother tongue, mathematics and the first foreign language, but art, music, physical education, discovery of the world and religion/ethics are important. According to the recommendations of the Standing Conference of the European Ministers of Education and Cultural Affairs (June 2015), “the task of the primary school is to enable basic school education in a joint educational programme for all children. The goal is to acquire and extend basic and adaptable competences. These include above all the key competences of reading and writing as well as mathematics, which form a basis for not only all other educational areas in the primary school but also for continuing education as well as lifelong learning and independent appropriation of culture.”.



For some years now, primary school curricula in Europe (and around the world) have included a methodology for integrating STEM (or STEAM) subjects into the curriculum.

From the point of view of mathematical knowledge in primary school, and the application of Algorithmic Thinking, we can divide the Learning Objectives into two categories whose Learning Activities are intertwined: Geometry and Arithmetic.

### Maths

Algorithmic thinking skills can be developed and improved through play-based activities including maths concepts.

#### 1- *Geometry and the sense of space.*

In primary school, Algorithmic Thinking activities and games can focus on spatial and measurement education. The sense of space concerns the relationships of right/left, above/below, specularity, symmetry, repetition, rhythm, distance, measure. For the development of these competences Algorithmic Thinking is essential. One can start with unplugged games and scenarios. These include the activity of mapping the classroom, the school, the garden. Sports or physical



education games involving recognition of position, space between children, distances. Children can learn to 'unpack' assigned tasks by drawing the steps they need to take to get to the solution. Or they can reproduce them through an exercise, a dance, a game.

They can then move on to use Scratch where skills of space, measurement, symmetry are brought into play. (Grover and Pea, 2013).

## 2- Algorithmic Thinking and the Sense of Time

As far as arithmetic is concerned, one can start by educating the sense of time, using clocks or various games. In this way, you can begin to plan the day with the children, drawing up a programme and breaking it down into various activities, assigning names and times.

In addition, the use of small robots (e.g. Lego WeDo 2.0) will involve mathematical concepts as a whole.

In a research activity, KIBO robotic kit was used to improve the algorithmic thinking skills of preschool children by using the geometrical shapes (circle, square and triangle) and numbers together with other learning areas (Bers, González-González & Armas-Torres, 2019). In this study, observed that robots can be used to improve Maths skills of children (age-appropriate) and they can be integrated with each other through play-based activities.

In the study carried out by Highfield (2010), the robotic toys Bee-Bots and Pro-Bots were used and 33 children attending preschool participated in the activity. At the end, the results showed that the integration of robotic toys into the preschool learning activities supported with engaging tasks fostered children's mathematical thinking and sustained engagement.

In the study, Mısırlı & Komis (2014) carried out, it was observed that the application of learning scenarios in preschools could help develop the knowledge of children about the preliminary concepts of programming by programmable toys. Employing the cognitive potential developed the mathematical skills as well as programming and problem-solving skills.



## Social Emotional Learning

Bers, González-González & Armas-Torres (2019) indicated that the KIBO intervention was successful in fostering communication and collaboration skills of preschool children (at the age of 3-5). The effect of the research activity on promoting content creation and creativity was moderate and low when it came to behaviour choices and community building. The researchers also stated that computational thinking skills could be integrated into the preschool curricula in conjunction with other subjects (learning areas). In this way children will be more acquainted with what they learn.



Futschek and Moschitz (2010), stated that benefiting from team games requiring collaboration and communication to teach an algorithm improves children's social skills and this can increase the interaction between children, help them trust each other and become more willing to participate in the learning process.

*Self-awareness:* Self-awareness is the ability to recognize and name one's emotions, including emotional needs, strengths, and limitations. Both by means of unplugged games and software (Scratch, Alice) it is possible to imagine story-telling activities involving social emotions, also by recalling small events with the children.

*Self-Management:* Self-management is the ability to regulate emotions and behaviors so that goals are achieved. Since perseverance is the basis of self-management, through games and AT activities it is possible to work with children on overcoming the brokenness resulting from failure. The importance of the *fail forward attitude*! This means that students need to know how to learn from their mistakes. Students should apply what they learned to make improvements and eventually succeed. Failure is part of the engineering process! (Hilppö and Stevens, 2020).

*Social Awareness:* Social awareness is the ability to understand what others are feeling and put themselves in their shoes. This helps us relate to others and empathize with them. It is related to:

*Relationship Skills:* it refers to the ability to work well together in teams, handle conflict well, and generally have positive relationships with others. Analyzing these behaviors can be crucial in students gaining mastery over these social skills. STEM education is well-suited for learning about empathy and other emotion-related skills (Castano2012). SEL (Social Emotions Learning) has been defined as "the process of acquiring core competencies of understanding and regulating emotions, developing positive goals, understanding the perspectives of others, maintaining positive social relationships, making responsible decisions, experiencing empathy for others, and managing challenging interpersonal situations" (Elias et al. 1997). (Halberstadt, Denham, and Dunsmore2001).

Other important elements in ECE social-emotional learning, which can be considered in this project are (Illinois Early Learning Guidelines, 2015:

- Emotional regulation - Children demonstrate the emerging ability to identify and manage the expression of emotion in accordance with social and cultural contexts.
- Behaviour regulation- Children may be able to demonstrate limited self-control over behaviour by responding to cues found in the environment. Children also begin to use more complex strategies to help manage feelings of impulsivity.
- Attachment relationships- Children form secure attachment relationships with caregivers who are emotionally available, responsive, and consistent in meeting their needs. Children begin to use nonverbal and verbal communication to connect and reconnect with their attachment figure.
- Emotional expressions - Children continue to experience a wide range of emotions (e.g., affection, frustration, fear, anger, sadness). At this point in development, children will express and act on impulses, but begin to learn skills from their caregiver(s) on how to control their emotional expression.
- Relationship with adults - Children demonstrate the desire and develop the ability to engage, interact, and build relationships with familiar adults. Children actively seek out familiar adults and begin to show an interest in adult tasks and roles.
- Self-concept - Children become aware of themselves as distinct from others both physically and emotionally. During this period, children often struggle with the balance of being independent and needing nurturing from their caregiver(s).
- Relationships with peers - Children demonstrate the desire and develop the ability to engage and interact with other children. As play and communication matures, children begin to seek out interactions with peers.
- Empathy - Children demonstrate an emerging ability to understand someone else's feelings and to share in the emotional experiences of others. Children begin to notice different emotions that other children are expressing and may begin to respond to these emotions.
- Self-Care - Children demonstrate the desire and ability to participate in and practice self-care routines. Children become active participants in addressing their own self-care needs with the support of the caregiver.
- Social communication - Children demonstrate the ability to engage with and maintain communication with others. Children increase their capacity for complex interactions as they use a greater number of words and actions, in addition to better understanding the rules of conversational turn-taking.
- Concept development - Children demonstrate the ability to connect pieces of information in understanding objects, ideas, and relationships. Children begin to understand object representation and begin to use verbal and nonverbal communication with object use.

Another important element in the Social Emotional Learning is the concept of *global citizenship*. Global interdependence requires today's students to become globally competent and socially responsible (Breitkreuz and Songer, 2015). Global citizenship focuses on the extent to which individuals respect the global landscape, demonstrate an awareness of social responsibility in the search for community-based solutions

(Schattle2008), and understand people, cultures, events, and systems from a global perspective (Ibrahim2005). Many experts believe that social justice and global approach to learning and teaching in the STEM areas may contribute to the understanding of social issues and the development of a democratic society (Amadei and Sandekian2010).

All these social skills can benefit from applying AT to games and activities where children are confronted with tasks, goals, failures, team and cooperative working. Storytelling designed using drawings or other analogic tools (unplugged programming) and then software brings these skills into play in an important way. Start with an autonomous division of tasks and let the children organise their work according to spontaneous groups. Observe the progress of the work and promote error analysis. (Hoffman et al, 2020).

## Social sciences

**Social sciences** in preschool education include many themes which are easy to adapt in PlayBL and algorithmic thinking skills. Social sciences are defined as the “part of a school curriculum concerned with the study of social relationships and the functioning of society” (Seefeldt et al. 2014). The knowledge and skills learned through social sciences prepare children to become informed and engaged citizens of their country and the world. Including social sciences in learning young children, provides an opportunity for adults to support children as they are developing a sense of self and an awareness of their family and community. Preschool programs in Slovenia, Finland, the USA, and many other countries have a formal social sciences or social studies curriculum and many everyday preschool experiences provide a foundation for social studies skills.



Initially, young children’s focus is on themselves and their family. As they enter preschool, their world widens to include the school or caregiving environment. And as children grow and develop during the preschool years, they begin to understand that though they are individuals, they exist not only within a family and school but also within other larger contexts, such as their neighbourhood and community. They begin to see that they have a role to play within each of these contexts: They are a son or daughter, a sister or brother, a student or friend, a neighbour or community member. Young children learn how to act as a member of these wider communities, being loving, helpful, respectful, and contributing to the greater good. All these themes are excellent opportunities to learn algorithmic thinking skills through PlayBL.

At the same time, they are becoming aware that there are other members of these communities who make contributions to their own well-being and that of the other community members. They are fascinated by police officers and fire-fighters. They imitate doctors, nurses, grocery clerks, and teachers. Preschool teachers can lead them in studies of topics within their community, including businesses, community services, and the jobs and responsibilities of adults, which are all overlapping with algorithmic thinking skills, as in many of those themes we can set board games, playing corners for free play or other PlayBL activities which would facilitate algorithmic thinking. These studies enable children to develop the intellectual habits of investigation and inquiry as they learn

how to transform their curiosity into questions and then represent what they have learned using developing skills in language, fine arts, and play (Licardo, 2017).

As children learn about broader communities and their members, their sense of geography expands. They become aware that there are other neighbourhoods, other cities, and a larger country. They begin to see how these spaces and locations can be described and studied using maps, pictures, and diagrams. As they enter the primary years, their world will widen even more, and they will begin to understand that other communities exist in other environments. Their investigations in these early years enable children to have confidence and enthusiasm for finding answers to the compelling questions of the social sciences as they continue in their schooling. By incorporating social studies in the early years, teachers are establishing the foundation for a democracy. They help preschool children to develop group participation skills, such as social negotiation and problem-solving, communicating about one's needs, and making decisions as a group. Experiences in social studies provide a foundation for the skills needed to become an active, aware, and productive citizen (Licardo, 2017).

### Music

Sense of rhythm and music are often associated with mathematical skills. But, unlike the latter, musical skills do not generally present any obstacles or difficulties. There are examples of "Fostering Computational Thinking in Primary School through a LEGO-based Music Notation" (Baratè et al, 2017). Or, of "Integrating Computational Thinking with a Music Education Context" (Bel and Bell, 2018).

KIBO robotic kits can also be programmed with blocks to dance with music. Bers (2020), explains that preschool children work in a collaboration to determine the dance steps (forward, backward, shake, beep, turn on the red and blue lights, etc.) to make KIBO dance the Hockey Pokey.

Another programming application (Legato) encourages algorithmic thinking both in the analytical attempt to reconstruct a known music theme with blocks and in response to changes in associations and create a new melody (Baratè, Ludovico & Mauro, 2019).

### Language, Narrative, and Storytelling

Narration includes a sequence of events and is a very suitable way of integrating algorithmic thinking into preschool curricula. In a research activity, an event was narrated with the visual cards and children were asked to create the card sequences in a logical order according to the narration. The majority of the children (15 out of 25) were able to place the cards in a logical sequence, while the other children succeeded it after trial-and-error processes and several self-corrections. 4 of them failed to order the cards in a logical way. Children helped each other during



the process (Lavigne et al, 2020). This shows that preschool children can acquire algorithmic thinking skills such as sequencing and troubleshooting the errors through trial-and-error processes.

### Play & Sports

Scharf (2007) designated and conducted a play with robotic kits called Tangicons in a preschool and a primary school and the research activity results showed that the preschool children were very fast learners who can recognise the connection between the Tangicons (blocks used for programming) and LEDs (Light bulbs in different colours). Research findings revealed that the children had some difficulties in remembering the sequences at first and they needed to check the sequences at every step, but they learned very fast and started to follow the sequences without looking up. The activity was planned, taking into account the children's attention span and their need to move around at intervals, and running and game activities requiring both fine and gross motor skills were placed into the play. Participating children mostly (7 out of 8 in the preschool) told that they liked the play very much.



Strnad (2018), carried out play activities with preschool children to facilitate them to perceive how robots work and comprehend how algorithms are formed. Blindfolded children received the commands and took steps forward, backward, turned right and left and reached the predetermined destinations by complying with the commands. They established connection with the functioning of the robots in this way. During the activities, children used Lego toys to construct their animal robots. In this way, they also revised the names of the animals and worked on their shapes. This also helped children reinforce their knowledge about natural science. During the activity a story was also created for children to keep their attention alive. It was observed that children were very engaged and eager to play more. This also shows that a learning scenario for the improvement of algorithmic thinking skills can be designated in a way that it includes more than one or two learning areas.

### Nature and Science

The Algorithmic Thinking is perfect for organising small science experiments in physics and life science.

Children will be confronted with the need to set up the programme, prepare a GANTT, divide the work, and collect the data.



# ALGORITHMIC THINKING SKILLS IN PRESCHOOL EDUCATION

Early childhood education is a context that provides children with opportunities to solve problems from different types and complexity, based on their interests and motivations. Children benefit from being encouraged to define goals, plan tasks, rehearsing and comparing different resolution strategies, and developing critical thinking about their achievements.

One way that working with algorithmic thinking with preschool children can contribute to the child's development is in laying the groundwork for the development of Computational Thinking. Wing (2016) described Computational Thinking as "taking an approach to solving problems, designing systems and understanding human behaviour that draws on concepts fundamental to computer science". Computational Thinking applies to a large spectrum of disciplines and areas and involves the idea of solving problems, conceptualizing and thinking at multiple levels of abstraction. Computational Thinking is more than coding, since it is a thought process. Based on Wing's seminal work, many authors recognize elements such as abstraction, generalization, decomposition, algorithmic thinking, and debugging or evaluation as parts of this process.

In everyday kindergarten practice, when children enjoy activity and are completely committed to it, investigating, asking questions, searching for solutions on their actual problem they engage in, most often in a project activity based on the children's interest, in numerous documented children conversations one can easily detect the same pattern. Children like tools that can help them to understand, to get answers, to enlighten new questions and satisfy their curiosity. In that precise moment, kindergarten teacher confirm that children are using and combining efficient and effective steps and resources to get their ideas into realisation (Slunjski, 2001, Miljak, 2009, Vujičić, 2013), and even use the real scientific methodology (Gopnik et al. 2003).

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## Scope

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Algorithmic thinking is a problem-solving skill related to devising a step-by-step solution to a problem. Algorithmic thinking can be connected to deep procedural knowledge, which involves understanding procedures, associated with comprehension, flexibility, and critical judgment (Lockwood et al., 2016). An algorithm encompasses a set of actions and understanding about their intentionality to reach a specific goal, involving flexible thinking. Moreover, by designing an algorithm, the sequences of steps identified can be reused in another scenario or context.

In practice, an algorithm results in a series of steps ordered in a specific sequence to achieve a goal. In early childhood education, a linear algorithm can enhance sequencing tasks. Retelling a story in a logical way, ordering objects in a logical pattern, organizing tasks of daily routines, such as washing their hands, or arranging their school bag or lunch box to go to school, are tasks that can involve children in algorithmic thinking (Bers, 2020). Children begin to understand that they can achieve the same results with different algorithms, but they get better results with some of them. In this way, they feel challenged to improve their algorithms. They also understand they can reuse an algorithm in different tasks. As they grow, they can use more complex representations to describe their algorithms, beginning to develop abstraction.

Educators can scaffold children's discoveries and ideas by intentionally leading them to develop problem solving abilities, one of the transversal processes to introduce mathematics in early childhood education. Problem solving calls for skills such as analytical ability, creative thinking, initiative, logical reasoning, and persistence. It is important that, from an early age, children can experience meaningful experiences like these. In particular, skills involved in problem solving help the development of algorithmic thinking, as a systematic way to face challenges of different nature.



Children learn by doing, participating, and exploring, through activities organized by themselves or encouraged by the educator with a rich, varied and interesting offer of materials (Malnar et al. 2013). The surrounding is the most important feature of learning processes for children, wherein carefully prepared and prudential space (indoor or outdoor) make the crucial difference and have the role to strengthen learning process, rich and powerful with learning situations, for their own experimenting, researching, checking out for their own their understandings and hypothesis. Afterwards, children are trying the same or similar method in different situations.

At the same time, computational thinking can generalize and transfer the problem-solving process to a wide variety of situations (McClelland, Grata, 2018). For example, confidence in dealing with complexity, persistence

in working with difficult problems, tolerance for ambiguity, the ability to deal with open-ended problems, and the ability to communicate and work with others to achieve a common goal or solution. Additionally, Sneider, Stephenson, Schafer and Flick (2014) point out that when pupils approach a problem with a background of computational thinking, their knowledge can help them see the systems that are before them and develop new problem-solving skills within any content area. In preschool education, the problem solving is depending on opportunities children have to try, fail and try again and succeed. That is, algorithmic thinking skills in preschool education depend on the experience children have had and therefore those stimuli are crucial in developing skills detecting and formulating problems, estimating strategies and positive attitudes in searching for solutions. In this process, one of the greatest importance is collaborative learning and cooperation abilities, which are crucial in positive outcomes for all involved parties. The depth of children's investigations is at the same time the depth of their learning, so its interconnectedness is necessary and coherent, and most important of all, stands as a child's need instead of a desire. There are infinite ways that children can express, explore, and connect their thoughts, feelings, and imaginings. These languages, known as The Hundred Languages of Children, are symbolic and are open to the endless potentials in children (Malaguzzi), and among them are algorithmic thinking skills.

Mortimore (1999) points out that in early aged children we cannot separate learning from the context in which it takes place and what is learned is in strong connection to the learning situation. The same author calls learning situations 'co-production of knowledge through activities', he sees learning as 'inserted into the environment'. Learning and gaining knowledge are conditioned with interactions between acting individuals in the context they act, jointly build knowledge in interactions with the physical, social and cultural environment. Individuals and context are in constant interaction, they define each other and give each other's recognizable identity. That is why context is needed to be seen as an integral part of learning and building knowledge. In the process of gaining new knowledge, the most important features are natural curiosity, audacity and fearlessness, learning by doing, exculpation of criticism and of social rejection, and all of them are present in preschool age (Gopnik et al. 2003), therefore children at that age can be „great recipients“ of algorithmic inducement and activities.

Algorithmic thinking primarily develops solving various problems that reflect real issues, through which the application of knowledge from other areas, especially science, mathematics and logical disciplines is necessary (Mezak & Papak, 2018).

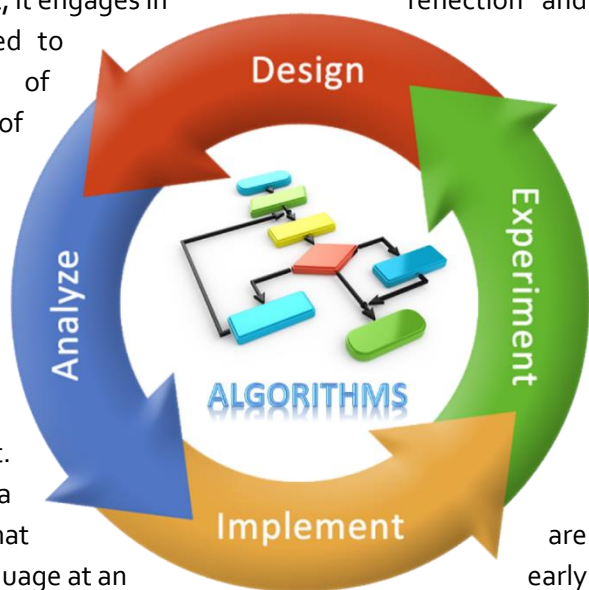
To be able to see the whole picture, realise the problem situation or the destination to achieve is one of the important aspects of algorithmic thinking. This facilitates to comprehend the meaning and power of formal notation through which one can describe the action that he/she will perform (Dagienė, 2020). Then, to be able to separate the problem stages into smaller pieces (algorithms) to facilitate the progression is another aspect. A problem-solving process generally includes stages to be completed. Therefore, to be able to decide which steps should be taken through which sequence means we grasp the success already. As we can see here, algorithmic thinking is important not only for the improvement of programming skills but also for better life skills. When we foster children's algorithmic thinking skills by integrating it into different learning areas such as music, maths, art or sports, we will have doubled the educational acquisitions and facilitate the learning and problem-solving processes of children.

Acquisition of algorithmic thinking skills can make ordinary tasks more effective and facilitate them as purpose oriented. As a matter of fact, algorithm concepts used for programming and computation aren't as abstract as they look because they are the production of the human brain based on its perceptions from experiences and

stems from human reasoning. We use algorithms every day and pay almost no attention to what we do, but all algorithmic thinking skills match our problem-solving activities that we deal with in everyday life (Lamourine & Farrow, 2020).

## Future Benefits

Research of Voronina, Sergeeva and Utyumova (2016) suggests that algorithm skills development in preschool children of 6-7 years of age is a prerequisite for preparing them for successful transition to the next stage of their studies. The fact of the greater significance is that the process of algorithm skills development may contribute to motivation development, cognitive activity, goal setting, planning, evaluation, and self-monitoring. Above all, it may have a positive influence on the learning activities in future schooling. Besides, results confirm that it is possible to start affront „new literacy“- algorithmic thinking very early, at 3 years old (Bers, González-González, Armas-Torres, 2019). In this early learning process, the strategies used are communication, collaboration and creativity, which are the lifelong important skills that always need to be sustained, integrated in all forms of learning and living, implying children in the early age learn by doing. Those used strategies are also ground strategies for a holistic development and set the basic principle for encouraging critical thinking and active citizenship skills. For preschoolers, critical thinking involves the ability to think clearly and rationally in order to understand logical connections between ideas. In fact, it engages in reflection and independent thinking, where children must be encouraged to become active learners rather than passive recipients of information. Kindergarten teachers participating in study of Bers, González-González & Armas-Torres (2019) exhibited autonomy and confidence to integrate coding and computational thinking into their activities, connecting concepts with art, music and social skill sets. Through the evidence found in this study, this research contributes with examples of effective strategies to introduce robotics, coding and computational thinking into early childhood learning. All of it can refer to an algorithmic skill set. Furthermore, early exposure leads to scientific phenomena bringing to a better understanding of the scientific concepts that later learned in a formal way, as well as usage of scientific language at an age affects the later development of scientific concepts (Miljak, 2009).



According to Arfe, Vardanega & Ronconi (2020), gains in coding skills are transferred to children's executive functions: planning and response inhibition. They also found out that transfer of coding effects is more evident for planning than for response inhibition. Planning is important in an algorithmic way of thinking, but it can be important for all other child' activity, and the most important one, play. Nevertheless, the use of different cognitive tasks to assess the degree of cognitive transfer is important for numerous reasons and capacity for implication to child' life. There is a theory that supports various forms of learning, it explains and justifies diversity in human thinking, which cannot be applied to any computer language. It is the theory of multiple intelligences (Gardner, 2011), which helps to understand and broaden the definition of intelligence and to outline several distinct types of intellectual competencies. At the same time, it comprehends and gives perspective to children's learning process.

On the other side, computational thinking is linked with critical thinking, STEM (science, technology, engineering, and math) learning, and project-based learning. Additionally, by employing the language of computational, including algorithmic thinking across multiple disciplines, children can make powerful connections between their group and beyond. When faced with challenges that are difficult to categorize, children will have a rich toolkit to draw from that crosses their specific interests or traditional subject borders later in school. Bringing computational thinking into the preschool group is simple, developing new skills and attitudes with introducing some ambiguity in projects, linking it to real-world examples and evidence (Sheldon, 2017).

Algorithmic thinking skills support the development of general reasoning, problem-solving and communication skills by giving students the skills to fluently interpret and design structured procedures and rule systems. Such procedures and rule systems can be found in a wide range of curriculum areas, with complex rule systems frequently found in the syntax of languages, in scientific classification, and in legal reasoning. (Breese, 2018). Shigrov (2018) adds that the earlier any skill can be appropriately introduced, the better. This allows more time to fine-tune elements in thinking, approach or perhaps motor/mental/cognitive skills required. With algorithmic thinking, it means younger children and pupils have more time to develop effective habits in their processing of tasks and problem solving. It might also be worth considering the paralleled step-by-step nature of algorithmic thinking that could lend itself to reduced anxiety in learning.

Breaking tasks down into smaller and more manageable 'chunks' follows a system and pattern, an algorithmic approach. Furthermore, Snalune (2015) describes that much of modern-day business is about problem solving - whether that's making small improvements to enhance the efficiency of a business, or creating breakthrough products and services for consumers. It is not the future; it is the present situation that computational thinking runs through every aspect and function of a modern business. „It has become more crucial in the 21st century workplace where so much is now data-driven - analysing consumer behaviour, the movement in financial markets and the performance of public services, like health or policing, are just a few job roles that require individuals to be able to think through problems in a way that a computer could understand"(Snalune, 2015).

One needs to be able to understand and think through business problems using the aforementioned concepts, it seems to be vital, even if someone is not then in a position to create a solution using programming languages and computers. That kind of thinking skills are beneficial to careers in the majority of human guided sectors, including consumer products, business and financial markets, energy, travel and tourism, or public services such as healthcare, education and law and order. It means that workplaces need employees to take an active role in thinking problems through and creating solutions. Computational thinking can be applied to any function of a commercial business or public service. For example, planning and forecasting are based on patterns of generalisation or abstraction, designing the user journey for a retail e-commerce site involves being able to break a problem down into its component parts, using decomposition techniques, and constructing a sequence of steps to solve the issue using algorithmic thinking.

## GOOD PRACTISES IN PRESCHOOLS

Computational Thinking (CT) is the term that refers to the key concepts and ideas of the subordinate fields of information and computer sciences. In doing this, CT “involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science”, and it encompasses “a range of mental tools that reflect the breadth of the field of computer science” (Wing, 2006, p. 33). Thus, it describes a mental activity for the formulation of a problem by means of a computational solution.

Although the notion of teaching CT was announced in the late 20<sup>th</sup> century (Papert, 1980), currently, the term has gained interest from policy makers, practitioners, and researchers in the field of education. In that, CT is proposed as a fundamental skill that is to be taught to every student just like reading and writing (Wing, 2006). Correlatively, there is an increase in the amount of grey literature on CT, which are supported by policy-oriented documents. For instance, European Commission (2016) clarifies the significance of CT together with its integration into education. Therefore, the member states are invited by the New Skills Agenda for Europe (European Commission, 2016) to invest more in the formation of digital skills throughout all spectrum of education.

Quite similarly, CT and its potential advantages in compulsory education have also been examined by means of a research basis. To elaborate, CT is regarded like a skill-set which requires the acquisition of problem-solving skills (Charlton & Luckin, 2012), making inferences from abstract objects (Armoni, 2010), dealing with challenging cases (Weintrop et al., 2015), simulating scenarios via computer models (Creative Learning Exchange, 2015), and collecting and analyzing data by means of algorithms and simulations (Gretter & Yadav, 2016).

In this respect, as an important ingredient of CT, algorithmic thinking (AT) is defined as the ability to comprehend, utilize, evaluate, and design algorithms to solve a wide range of problems (Brown, 2015). Algorithmic thinking is defined as the precise, clear, and detailed thinking of the steps which are required to achieve a specific goal (Brown, 2015). Since this ability is unique at any stage of problem-solving (Futschek, 2006), students should develop their algorithmic thinking abilities as one of the fundamentals of education environment. Herein, the algorithm is regarded as the abstraction of a process in which sequence of steps (as inputs) are followed to accomplish a desired goal as an output (Wing, 2011). Thus, algorithmic thinking “as a way of getting to a solution through a clear definition of the steps” (Csizmadia et al, 2015, p. 7) caters students with the ability to come up with solutions to prominent problems through systematic thinking.

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### Studies about Algorithmic Thinking Skills & Good Practices in Preschools in Turkey

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As an abstraction of a process which takes input(s) into output(s) by means of sequential steps in order to reach a desired goal, algorithmic thinking has been a part of school curriculum in recent years in many parts of the world. Among these, Finland is one of the first European Union countries which introduces algorithmic thinking together with programming as a mandatory, and cross-curricular educational activity from Grade 1. Other countries have also founded policy initiatives in this direction. Correlatively, Turkey has integrated CT as a part of the new national curriculum for primary and secondary schools.

	Austria	Czech Republic	Denmark	Finland	France	Greece	Hungary	Italy	Lithuania	Poland	Portugal	Switzerland	Turkey
Fostering logical thinking skills													
Fostering problem-solving skills													
Fostering other key competences													
Attracting more students into Computer Science													
Fostering coding and programming skills													
Fostering employability in the ICT sector													

**Figure 1. Rationale for integrating computer thinking into the school curriculum according to the survey by Ministries of Education** [Source: Kampylis, P., & Punie, Y. (Eds.). (2016). *Developing computational thinking in compulsory education: Implications for policy and practice*. Joint Research Centre, European Commission.]

Besides, coding has also been included within the school curriculum through text-based programming, block-based programming, robots, and the like. However, the integration of algorithmic thinking into the school curriculum is fairly limited in terms of early childhood education. There are studies conducted on the development of algorithmic thinking skills of primary school (Kalelioğlu, Gülbahar, & Kukul, 2016; Yavuz Mumcu & Yıldız, 2018), secondary school (Aydoğdu, 2019; Doğan & Kert, 2016; Oluk et al., 2018; Kırçalı, 2019; Korkmaz et al., 2015; Namlı & Şahin, 2017; Üngör et al., 2020; Yünkül et al., 2017;) together with middle and high school (Oluk, 2017), high school level (Demir & Cevahir, 2020), university level (Akkaya & Öztürk, 2020; Durak, 2009; Düzgün, et al., 2001; Gökoğlu, 2017) students' development of algorithmic thinking skills have been touched upon. On the other hand, there are also studies conducted with preschool students in relevant literature (Altun, 2018; Atabay, & Albayrak, 2020). Another example is Bilge Kunduz activity (Bebas International Challenge on Informatics and Computational Thinking) that has been organized in many parts of the world since 2004. First pilot study was conducted in the same year in Turkey. This pilot study also included 5<sup>th</sup> and 6<sup>th</sup> graders within the scope of answering easy-level, and advanced-level questions. According to the results, it can be deduced that algorithmic thinking skills of the Turkish students should be enhanced. As reported, there is still a scarcity of research and related practices in the case of early childhood education.

According to the results of the studies, it is noted that algorithmic thinking is related to problem solving (Altun, 2018; Demir & Cevahir, 2020; Düzgün, et al., 2001; Namlı & Şahin, 2017) and critical thinking (Doğan & Kert, 2016). Besides, it is also marked in the literature that Scratch improves algorithmic thinking (Oluk et al., 2018; Yünkül et al., 2017). Likewise, Üngör (2020) concludes that the use of Flowchart increases the effectiveness of teaching in algorithm education. On the other hand, in the study conducted by Kırçalı (2019), it is reported that the algorithm teaching even without a computer is as effective as that of in the computerized form. Whereas Atabay and Albayrak (2020) have reported that providing algorithm teaching in preschool by gamification

increases their active participation and willingness, Durak (2009) has remarked that the use of algorithms has a positive effect on students' achievement. Finally, Gökoğlu (2017) has conducted a metaphorical analysis on the concept of algorithm, and the opinions about algorithm writing and teaching are examined in the study conducted by Akkaya and Öztürk (2020). In the light of these, it is apparent that there is a scarcity of research conducted within the scope of algorithmic thinking in Turkey. It is also observed that most of the studies have entailed students from either secondary level or high school level as a sample.

In this vein, it is a crystal-clear fact that students' cognitive developmental levels and their ages as a part of their characteristics play a vital role in the utilization of computational and algorithmic thinking skills (Atmatzidou & Demetriadis, 2016). Quite similarly, developing countries targets at enhancing their students' algorithmic thinking skills and qualifications (Zsakó & Szlávi, 2012). Therefore, it can be interpreted that teachers should plan, prepare, and carry out special educational activities and new pedagogies for improving students' algorithmic thinking skills from the very early ages. In this respect, preschool education period is a path to develop both computational thinking and algorithmic thinking skills by means of robotic coding (Di Lieto et al., 2017), storytelling (Soleimani et al., 2019), mathematics learning (Palmer, 2017), visual programming tool ScratchJr (Sullivan, Bers, & Pugnali, 2017), and/or games (Kanaki & Kalogiannakis, 2018).

In terms of teacher education in Turkey, there is no study reported on the development of algorithmic skills. Accordingly, it is determined that there is a need to develop a project to eliminate this gap in the field. In terms of sample selection, it is assumed that providing algorithmic thinking skills to preschool teacher undergraduate students, who are in fact future code writers, will contribute to early childhood education. As a matter of fact, starting this education in early childhood to move forward in the lifelong education process will undoubtedly yield positive results. Quite similarly, it is a crystal-clear fact that relevant literature has blossomed positive results on the basis of games for the development of algorithmic thinking skills. According to the study conducted by the European SchoolNet in 2015 with the participation of 21 Ministries of Education, coding education is a part of the curriculum of 16 countries (at national, regional or local level) (Balanskat & Engelhardt, 2015). In our country, it has been put into practice under the name of "Information Technologies and Software" in the secondary school curriculum since 2013 and in all primary education institutions since 2018 (MEB, 2018). The importance of programming education has been recognized in our country, and programming courses have been included in the education curricula of the country as well as in the education curricula of many countries (Saygıner & Tüzün, 2017).

Within the scope of programming and coding education, many activities, projects and events have been carried out both by the Ministry of National Education and other organisations/institutions such as universities, banks, non-governmental organisations and software companies. Some of them are; Bilişim Garajı (Informatics Garage), Code Week, Kodla(Ma)nisa, Yarını Kodlayanlar (Those who code the future) and Garanti ile Geleceği Kodla (Code Future with Garanti). Türkiye Bilişim Derneği (Informatics Association of Turkey) organised an event called "Computer Programming; Easy Peasy" in May 2014 with the participation of at least 100.000 primary, secondary and high school students to write their computer programmes for the first time (Programlama Çocuk Oyuncak, 2014).

When the academic studies were investigated, seen that between 2008-2018, 78 articles (TUBİTAK ULAKBİM DATABASE) and 68 theses (CoHE THESES DATABASE) were written within the scope of programming education in Turkey (Eryılmaz & Deniz, 2019).

Thus, this project will attempt to develop algorithmic thinking skills in a game-based way. In this vein, it is believed that this project via game-based learning will guide the future code writers and contribute to the elimination of the gap in the field for the goodness of future code writers. Herein, this project will contribute to the development of algorithmic thinking skills in early childhood education since it aims to design a course program and related teaching materials by filling the gap to teach undergraduates from the department of early childhood education how to reflect the algorithmic thinking skills in all areas of early childhood education, and integrate it into the teaching of music, art, mathematics, drama, science, behavior development, and language development, which are all addressed in early childhood.

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## Studies about Algorithmic Thinking Skills & Good Practices in Preschools in Slovenia

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A systematic deployment of ICT use in the Slovenian education started in 1994, namely with the project of computer literacy (RO – Računalniško opismenjevanje). The aim of the project was to equip the Slovenian educational institutions with hardware and software (system and didactical), computer facilities, organise training of teachers in teaching with ICT, as well as realize development and research projects for new approaches to the use. We have set up the Slovenian educational network (SIO – Slovensko izobraževalno omrežje) and created the Trubar web-based catalogue of material and events, as well as organize promotion at home and beyond and the international conference MIRK. Thus, since 1994 until present day, the training of pre-school teachers, teachers and head-teachers, and servicing the Slovenian educational institutions with ICT, as well as other activities have been ongoing without greater interruptions in view of the annual national funds) (Strategic guidelines, 2016).

In Slovenian elementary education computational courses are part of elective curriculum, which means that students can choose courses related to algorithmic thinking and computer education only if they want, they are not obligatory. In school year 2016-17 only 17% of students (age 9- 11 years) have chosen course related to computer education. In secondary education students have obligatory course (Informatics) in the first year of gymnasium and in the second year of professional secondary education. Development of digital competences and meaningful use of ICT is included in all course curriculums in elementary and secondary education, however students are not assessed for ICT skills, so we can conclude that Slovenia has a lack of systematic approach in the algorithmic thinking and digital skills domain, because we mainly teach students how to use computers and not how to create or code (Krajnc, 2017). [\[ML1\]](#)

Ministry of Education in Slovenia had published Strategic guidelines for further implementation of ICT in Slovenian educational system by 2020 (2016). The purpose of the document is to place within the Slovenian education the current initiatives, policies and other documents of Slovenia, European Union and beyond. They defined several goals for digital education in Slovenia.

Goals closely related to preschool education are:

GOAL 1 – Didactics and e-material

Develop and test innovative pedagogical approaches, models and strategies of student-centered learning and teaching that rationalise the use of ICT at all stages of learning (including critical evaluation of the didactical

importance of ICT, necessary changes in teaching and learning, virtual environments of communication and cooperation, application of various sources, progress monitoring, assessment and (self)evaluation of competences, special needs, etc.). Develop didactical aids or tools (e.g. multimedia and interactive learning e-material, mobile and web-based applications, e-portfolio), and accordingly, adapt the existing educational approaches.

## GOAL 2 – Platforms and cooperation

Set up an open platform of information technology, e-content, (e-)services, pedagogical concepts and approaches, added-value models, as well as motivation mechanisms (e.g. positive legislation) in an open education. In this way, upgrade the Slovenian education network – SIO (including efficient use of technology, e.g. cloud technology), establish synergy environment for (interdisciplinary) partner cooperation of all stakeholders in development and research of efficient use of ICT in the process of education, including economically effective business models of IT implementation.

## GOAL 3 – E-competences

Raise the level of digital competence and enhance the use of ICT within the overall educational system, and contribute significantly to improvement of key competences and 21st century skills of students at all levels of education, as well as participants in adult education, namely on a premise of comprehensive development of competences of teachers, ICT coordinators, head teachers, higher education teachers and other education staff (formal education and continuous education and training) through effective forms of training (face to face and online), by strengthening the professional (e-)communities, active exchange of good practice, peer learning, as well as and providing quality (e-)services (counselling, support).

In the past few years, several large projects were launched which include development of algorithmic thinking skills for students, however, none of them is meant specifically for early childhood education.

For example:

Project E-school (2009–2013): the Ministry of Education, Science and Sport funded one of the biggest system breakthroughs through the funds of the European social and regional fund, namely in line with the Action plan for digitalisation of the Slovenian education until 2006. The ministry realised several public tenders and direct projects at public institutions (ZRSŠ and ARNES) under the name e-education (e-šolstvo): a) Development and implementation of the e-competent teacher and head-teacher norm via seminars; there were 177 developed or upgraded seminars; individual seminars include development and acquisition of separate competence (primarily, the seminars cover specific subject fields, some on the other hand cover the use in all subjects). There were 27 development groups set up. Individual development groups continue to work regularly – monitors and develops new approaches to teaching and learning. There are professionals from ZRSŠ/CPI, faculties and several practitioners from schools in the group. Thousands of teachers (annually roughly 8,000) and head-teachers attended the seminars at least 50% of time; they were distance-learning workshops.

Next activity was development and implementation of counselling, didactical aid and technical support to schools in a way to support the expansion of standard and new service tailored to individual schools, that is to the needs of the head-teacher, teachers and pupils. c) There were seven international conferences SIRIKT (web of education and research with ICT); annual international conference SIRIKT hosts 1,200 participants; č)

Organisation of e-school: shared planning, development, implementation and evaluation of the project and access point for users (schools, head-teachers, teachers, pupils, etc.).

[Project NA-MA POTI](#), with 90 participant schools, 21 of them are kindergartens, universities, and Slovenian Institute for Education. The goal of the project is among other development of didactical tools and strategies for vertical and horizontal teaching in STEM, with learning about authentic problems and use of digital technology.

Project [Inovative Pedagogy 1:1](#) in the light of 21st century competences: develop and implement and evaluate new approaches of teaching and learning with mobile devices used by all pupils in separate classes at certain schools; the focus being on inclusion of socially disadvantaged groups, too.

[Project e-Schoolbag](#), one has been developing along with e-textbooks in humanities the first universal e-services. The central ICT infrastructure has been set up at pilot schools to test all previous products in the process of teaching and learning (from e-textbooks to clients of e-services).

[Codeweek](#) is platform, where teachers can learn how to code. Available are learning lessons for teachers so they would be able to implement a learning lesson with coding in program Scratch. Available is also e-guidelines for coding in program [Blocky](#) and [e-course for coding in Phyton](#) for teachers.

[Vidra.si](#) is another Slovenian platform where teachers can learn about unplugged coding activities in elementary school, which might be interesting also for ECE.

We can conclude that in Slovenian education system there are systematic activities for development of algorithmic thinking skills through various projects and initiatives, however none of them is focused primarily on early childhood education. In the last Evaluation report for digital education in Slovenia (2018) there is a recommendation, that Slovenia should include computational thinking skills in curriculum from kindergarten to upper secondary school as obligatory content.

## Studies about Algorithmic Thinking Skills & Good Practices in Preschools in Croatia

According to the *Implementation Program of the Ministry of Science and Education for the period from 2021 to 2024* in the Republic of Croatia, one of the measures is the continuation of education reform. Earlier processes, such as the *Comprehensive Curriculum Reform*, were aimed at developing basic competencies for lifelong learning, increasing the level of functional literacy of children and students, the connection of education with the interests, life experiences, needs and opportunities of children and students, the connection of education with society and economy, and finally a clear definition of educational outcomes. Those outcomes are not only of a cognitive nature (knowledge), but also those that ensure the development of attitudes, skills, creativity, innovation, critical thinking, aesthetic evaluation, initiative, entrepreneurship, responsibilities, relationships with oneself with others and the environment, governance and many others. Therefore, the propensity for algorithmic thinking is recognized in these areas of development with the increased intention of unequivocally encouraging the application of learning and teaching methods, which enable the active role of the child in the development of knowledge, skills and attitudes with the support of (pre)school teachers and in interaction with other children. Among the basic guidelines of this document, a crucial feature of early and preschool education is play: "play is the foundation of children's development [*and it is necessary*], avoiding "schoolification" in early

and preschool education." ([http://www.kurikulum.hr/postavke\\_kurikuluma/](http://www.kurikulum.hr/postavke_kurikuluma/)). *National Curriculum for Early and Preschool Education* in Croatia fosters the principles of flexibility of the educational process in kindergarten, partnerships with parents and the wider community, ensuring continuity in education and openness to continuous learning and readiness to improve practice. Lastly, the openness to continuous learning rests on the very basis of curriculum development of early and preschool education, where the basis of the child's learning is the kindergarten' environment, which cannot separate learning content or subject areas. It implies that the child's learning takes place in the immediate environment and contents that are close to him or the child can consume them in close and understandable ways and thus discover new areas. Kindergarten curriculum implies overall educational interactions within the physical and social environment of the kindergarten, which includes children and adults, an educational concept that is jointly developed, co-constructed in a particular kindergarten and corresponds to the quality of conditions (physical and social environment) for living, learning and raising children in it. *National Curriculum for Early and Preschool Education's* postulates, "understanding the child's learning as a result of her/his active and engaged participation in various activities. Children learn through play, exploring and combining with other activities that are purposeful for them, i.e. through direct experience with a diversity of learning resources. In doing so, they enter a variety of interactions with other children and the adults who support them. Within the self-organization, research and discovery potential of children's activities are being strengthened, and those forms of preschool teacher's support are provided to engage children's thinking capacities that encourage them to reflect on their own experiences. Understanding of learning as described, it finds its theoretical basis in the theory of constructivism and socioconstructivism and the importance of encouraging the development of children's metacognitive abilities." (p.16). One of the basic tasks of the *National Curriculum for Early and Preschool Education* in Croatia is to ensure the preconditions for unhindered and as more as possible "natural" mobility / continuity in education, especially during the transition from kindergarten to school. The same crucial document for early education, *National Curriculum for Early and Preschool Education* encourages and empowers development of eight basic competencies for lifelong learning. This is the educational policy of the Republic of Croatia accepted from the European Union, and among those competences, two of them are close and relevant: first, mathematical competence and basic competences in science and the other, digital competence.

According to the document from March 2020, *Strategic framework for the digital maturation of schools and the school system in the Republic of Croatia (2030)* it is evident that learning of a child goes beyond the institution in which this process takes place. It is emphasized that the greatest benefit from the systematic planning of ICT in schools should benefit students who today make extensive use of technology outside school, their parents and in the long-term employers and society as a whole whose members are digitally competent citizens ready to live and work in modern environment. The vision is to encourage the development of students into responsible, globally competent and innovative citizens, and the mission is to support quality and innovation in the school system through the purposeful use of technology in learning and teaching, development of digital competencies and management of school institutions and processes. The Strategy of Education, Science and Technology (2014) among five identified objectives, highlights the encouragement of the application of information and communication technology in learning and education.

In Croatia, the following programs are implemented by organizations aimed at encouraging the activities of algorithmic thinking, coding and STEM:

- The "Step to Science" program implements the STEM program for children, up to several age groups, with programs for ages 4, 5, and 6 to 8 years. STEM is an interdisciplinary program, and for organizational reasons, it is arranged in a series based on the numbers 4: 4 Science, 4 Technology, 4 Engineering and 4 Mathematics ( $4^2 = 16$ ). PROBOTIKA is a program with less defined structure and it largely depends on the individuality and rhythm of progress, but in general, it deals with programming and robotics, block programming, learning Logo, using mBots, PROBOTs, microbits, various engines and sensors and accessible educational materials for programming such as KhanAcademy, Scratch, Tynker, Code.org, Kodable, Robozzle, etc. A child may or may not have prior programming knowledge because he or she gets the challenges he or she is always looking for. The same organization organizes the Winter STEM camp and similar thematic camps.
- Kindergarten "Mali svijet" from Lučko (near Zagreb) brings together children from 4 to 7 years (preschoolers, children of 1st and 2nd grade of primary school) who are interested in robotics, science and mathematics, and implements a program that takes place once a week in kindergarten. The program is consisted with interesting things through which children, guided by experts, will learn the basics of informatics and natural sciences and learn to operate sophisticated IT equipment.
- Kindergarten Opatija enriches its educational work by introducing a program of robotics and programming "STEM in kindergarten" The program is implemented in the form of workshops, and distributed by modules: robotics, programming and coding, design thinking, innovation and scientific experiments. Through the "hands on" approach and a large number of the latest equipment, each child acquires digital skills on an educational robot, tablet and a large number of modern didactic equipment. A great advantage of STEM workshops is the development of logical-mathematical competencies. Thanks to educational technology, whose role is increasingly pronounced in the current situation, the program "STEM in kindergarten" in the Kindergarten Opatija and partner kindergarten Bambi from Vrbovsko is currently being held online. The program is organized by the *Institute for STEM education and afterschool programs*, it brings together STEM educators (educational experts, engineers, scientists) who are dedicated to the early education of children in the STEM field. Working in the British education system, they have gained extensive experience in STEM teaching and working with children, and for the last three years they have been organizing STEM & sport camps for children aged 4-12 and conducting STEM workshops for preschool and lower primary school children.
- Kindergarten "Zeko" from Varaždin in 2017 joined (through a parent from kindergarten, a mother who is a computer science teacher) in one of the 138,000 activities of the Hour of Code, which were held in 180 countries, and also the only kindergarten Hour of Coding in Croatia. They played \*\*\*\* in space, acting as "Smješkić/Smiley" and looking its way for getting to the apple, during which the children gave him instructions in a form of code, thus coded without the use of a computer ("unplugged").
- Promoting algorithmic thinking during "Magical Day" project in kindergarten "Đurđice" Faculty of Teacher Education, University of Rijeka held workshop for promoting algorithmic thinking development on May 10th 2019. "Magical Day" project was organized as part of the program 27 neighbourhoods within the framework of the project Rijeka- European Capital of Culture (EPK) 2020. A series of short, creative and innovative workshops were adapted to preschool children and held for children from kindergarten "Đurđice". During the workshop, some algorithmic thinking skills were introduced to the children in a fun way, through games. Children participated in unplugged activities to learn how to navigate in space. They used worksheets (to solve the mazes) and led each other through the space (to practice terms left, right, up, down, back and forth). These

activities served to educators from the kindergarten as examples for encouraging the algorithmic thinking skills among pre-school age children.

"Could it be different?! *How do children do their researches?*" was a project focused on teaching children STEM contents through the experiential, collaborative learning as the foundation of a child's healthy upbringing. Cognitive-research workshops for children and joint research with experts enabled children to encounter different STEM phenomena (sound, light, wind, air, water, thermodynamics, statics...), but also understanding many unknowns, which prompted the child's innate curiosity and interest in discovery actions of things and phenomena. With experiences conducted in research with scientists from Association 'Zlatni rez' (Rijeka), the Višnjan Observatory and the Immaginaria scientifica (Museum of Scientific Research), the children had the opportunity to express themselves through different media, materials and techniques in creative workshops led by various experts and artists. Video documentation of the project finale is available at <https://vimeo.com/67833664>

## Studies about Algorithmic Thinking Skills & Good Practices in Preschools in Italy

### PNSD IN ITALY: A PLAN FOR EDUCATION IN THE DIGITAL AGE

By 2022, the study of computational thinking and coding should become compulsory in pre-school and primary education, in line with the national curriculum guidelines.

On the basis of the Motion No. 1-00117, approved by the Italian Parliament, the Government to take initiatives to gradually introduce, by 2022, the study of computational thinking and coding in kindergartens and first cycle of education as part of the compulsory digital curriculum, in line with the national curriculum guidelines.

In 2015, the Italian government (Ministry of Education) launched the PNSD (Piano Nazionale Scuola Digitale, National Plan for the Digital School) which structured - and funded - many activities dedicated to AT, and to Computational Thinking, tools being coding and educational robotics.

"This Plan is not simply a deployment of technology: no educational step can be separated from intensive teacher-learner interaction, and technology cannot be distracted from this fundamental 'human relationship'.

This Plan responds to the call for the construction of a vision of Education in the digital age, through a process that, for schools, is related to the challenges that society as a whole faces in interpreting and supporting learning throughout life (life-long) and in all contexts of life, formal and non-formal (life-wide).

This is confirmed by the High Level Conference of the European Commission in December 2014, several publications of the OECD Centre for Educational Research and Innovation, the New Vision for Education Report of the World Economic Forum (PNSD, <https://www.miur.gov.it/scuola-digitale>).".

The Digital Economy Index sees Italy in 25th place out of 28, with structural weaknesses in connectivity and human capital. The digitisation process has also been developed through resources allocated at European level under the National Operational Programme (NOP Education) 2007-2013 and through the training of teachers.

The most significant steps in this 5-years Digitalization of Italian Schools:

- The digital school, in cooperation with families and local authorities, opened to *BYOD (Bringg Your Own Device)*, i.e. policies whereby the use of personal electronic devices during teaching activities is possible and efficiently integrated. (Lodi, 2020).
- The *student's digital curriculum* was introduced, i.e. a way of certifying and enhancing the skills, both formal and informal, that students acquire during their school years, during school hours and outside school, including individually.
- The creation of a *single digital identity*, the teacher's personal profile will be associated with a wide range of administrative information and interactions (teacher file), as well as those relating the professional development, also financed by the resources allocated to the Teachers' Charter. In a single tool, therefore, there is a way to highlight the work in the classroom and at school, and therefore the professional portfolio that each teacher develops, starting from the probationary year and throughout their career; the wealth of training experiences of the teacher, built through the paths offered by the Ministry or independently, including through the Charter of the Teacher.r. (Gabriele et al., 2019).
- *Equipping schools with digital technologies*. In this context, digital technologies intervene to support all the dimensions of transversal skills (cognitive, operational, relational, metacognitive). But they also come into play vertically, as part of the literacy of our time and fundamental competencies for full, active and informed citizenship, as anticipated by the Recommendation of the Europeann Parliament and the Council of Europe.
- Specifically, for *Primary School*: PNSD has promoted "Programma il Futuro" (see action #17). (see action #17), a course dedicated to primary schools. Each primary school student already followed a corpus of 10 hours per year of logic and AT (called the 'Program the Future' initiative. (See Corradini, Lodi, Nardelli, 2017).

Other Italian PNSD Tools:

- making, educational robotics, internet of things,
- digital art, digital management of cultural heritage,
- reading and writing in digital and mixed environments, digital storytelling, digital creativity,
- Action #20 - Girls in Tech & Science

In addition, the Italian Ministry of Education has set up a close collaboration with several associations, including Scuola di Robotica, to carry out

- training of teachers and technical staff
- the organisation of coding and educational robotics contests
- collaboration with Europe through EU Code Week and EU Robotics Week

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## Studies about Algorithmic Thinking Skills & Good Practices in Preschools in Portugal

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Code has been relevant for Portuguese Early Childhood Education (at least) since 1997. In their first edition, the Portuguese Curricular Guidelines for Pre-School Education (Ministério da Educação, 1997) included computer

code as one of the codes children should get acquainted with. This meant its inclusion under the domain “spoken language and introductory writing”. It was stated that “code” was present and would be necessary in children’s lives and could be used in arts, music, mathematic or writing (Portuguese) (p. 72). This approach was positively singled out by the OECD report on Portugal: addressing the topic of ICT in the guidelines interconnected with other forms of communication and information learning (Taguma et al., 2012).

Early Childhood Education in Portugal includes 0-3 years old, outside the educational system, and 3-6 years old also called “pre-school education” that is the first stage of the Portuguese basic education system, part of a lifelong learning process. In 2016, the Portuguese Curricular Guidelines for Pre-School Education (PCGPSE) were reviewed. The content areas in this version are Personal and Social Development, Expression and communication (which includes Physical Education, Artistic Education, Mathematics and Oral and Written Language) and Knowledge of the World. In this second version, there are more mentions to technology, particularly in the Knowledge of the World area under “Technological World and Use of Technologies”. The document assumes children need to learn about, use and gain a critical understanding of the several technological resources that are now part of the life of all children, both for leisure (technological toys, computers, tablets, smartphones, television, etc.), as well as in their daily lives (electric mixer, heater, hairdryer, bar codes, flashlights, etc.). Besides playing with technology, it’s suggested that access to a computer in the school, or elsewhere in the community, is important as means of collecting information, communicating, organizing, processing data, etc. There is no mention of code or coding in this new version that assumes a more holistic approach to technology as part of the daily and future life of children.

There are, however, several opportunities to connect the learning that is valued in the OCEPE with algorithmic thinking. For example, in Oral and Written Language, the simplest activities, such as discovering words that start or end with the same sound or letter; identifying the number of syllables in a word by clapping hands, stomping, tapping the desk or speaking like a robot; games suppressing or replacing words in a sentence or following recipes to bake cakes, among so many other activities designed to explore and develop emergent literacy skills (Ministério da Educação, 2016), imply algorithmic thinking, as there is data analysis, decomposition, recognition of pattern solution components and decision-taking. In Mathematics, as well, since there is a strong emphasis on problem solving as one of the transversal skills of learning mathematics (Ministério da Educação, 2016). Finally, the Knowledge of the World área assumes as its purpose “to lay the foundations for structuring scientific thinking” (Ministério da Educação, 2016, p.86) as well as building an attitude of research that must be centered on the ability to observe and on the willingness to experiment with the hypotheses drawn. In a very close formulation to algorithmic thinking, it’s expected that children “Ask about reality, define the problem, decide what they want to know and look for a solution” (Ministério da Educação, 2016, p. 86).

There are several studies about technology in pedagogical practices in Early Childhood Education in Portugal (for example, Figueiredo et al., 2014; Mateus et al., 2014; Figueiredo et al., 2015; Ateus et al., 2017; Ribau et al., 2017; Loureiro et al., 2018; Gomes et al., 2019). But few experiences and studies particularly focused algorithmic or computational thinking. Three initiatives are worth mentioning.

EduScratch is an initiative aimed at promoting the educational use of a programming language – Scratch – by supporting, training and sharing good practices among the Portuguese educational community. It has been successfully implemented in grades K-12, with a naturally increasing level of complexity. The initiative aims to contribute to the creation and development of a teachers’ community of practice on the educational use of the

intuitive programming tool. The studies suggest Scratch promotes the development of computational thinking and has proven to have huge potential in developing different types of skills (digital and subject-related) in students (Tinoca, 2014). In Portugal, the initiative has been implemented through a partnership between the Directorate-General for Education of the Portuguese Ministry of Education and Science and its ICT Competence Centres. From an initial development based in the Setúbal ICT Competence Centre, in the Polytechnic of Setúbal, there are other centres across Portugal (Minho, Coimbra, Santarém and Évora). *EduScratch* in the School of Education of the Polytechnic Institute of Setúbal presents proposals to work with *ScratchJr* with preschool children, and indicates references to other school levels. In *EduScratch*, training workshops were held to educators, whose main objective was to promote the exploration, evaluation, construction and sharing of online educational resources for use in the school context. Associated with this project, there is also a national programming contest, *A Criar com Scratch!* (Creating with Scratch!), since 2016, that includes a strand for preschool (3 to 6 years old), as well as Basic Education (6 to 12 years old) (<http://projectos.esse.ips.pt/acriarcomscratch>). However, the impact at practice level has not yet been clearly studied. Project leaders have reflected on the impact of the initiative through levels of participation in national conferences and in *EduScratch* Day where students presented their projects and also from the growing number of student projects shared via the *EduScratch* online portal (Tinoca, 2014).

Part of the Portuguese strategy for implementing coding in Basic Education has been the involvement of the Municipalities who have some responsibilities over schools for Preschool and Primary Education. The project Smart City Lab for Kids grew from a partnership between the School of Education of Viseu and the Municipality of Viseu. The main goals were focused on working computational thinking and creative computing with primary schools children from the city, anchored in the following guidelines: working as project-based and curriculum based, exploring the potential of computational thinking to develop integrated and contextualized learning; collaborative work; creativity and diversity. Three hundred and forty six students and twenty teachers used programming and robots to explore and present ideas to turn their city into a smart city. Students presented a diversity of proposals such as games to explore the rehabilitation of the river, programming robots to care for community gardens or to model an intelligent building (Gomes et al., 2019). There are other initiatives that involve local authorities and local schools. One example is the project *Robótica e Programação na Educação Pré-Escolar* (Robotics and Programming in Preschool Education), promoted by the Municipality of Santa Maria da Feira, a “project that aims to encourage school children to enjoy programming and to learn programming in a fun and playful way” (<https://cm-feira.pt/robótica-e-programação-na-educação-pré-escolar>). The project *Pensamento Computacional na Educação Pré-Escolar* (Computer Thinking in Preschool Education) was another initiative which was presented by the Municipalities of Leiria and Porto de Mós with Competence Center *Entre Mar e Serra*. This project included a training program credited to teachers and involved 53 preschool education schools, in 2018, with the objective of developing computational thinking through development of the ability to plan and execute activities and mental skills to solve problems. In addition, robot programming learning kits were offered to schools.

Finally, the “KML II - Programming technologies and learning laboratory for pre-school and elementary school in Portugal” should be highlighted as it is focused on the introduction of computational thinking, coding and robotics activities in both pre-school and primary school with a cross-curricular approach (Monteiro et al., 2021). The project assumes technology teaching in initial years within a “globalizing dimension of education”, in which technology constitutes an instrumental component in the support of learning goals across the curriculum, in line with Portuguese legislation. The connection is made between the aims of the educational system of universal

access and inclusion for all students and equal opportunities with the way programming and robotics may offer hope for all children to achieve their full potential and effectively participate in a fully inclusive society. The authors consider that the several initiatives from the government together with the ICT Competence Centers have brought coding to school, but not primarily to classroom work since coding and robotics were mainly offered on a complementary basis (Monteiro et al., 2021).

In recent years, Portuguese educational policies have recognized the importance of developing digital skills from an early age. Information and Communication Technology (ICT) are assumed to be a cross-cutting area for the Early Years, both for Early Childhood Education, where there are several references in the different content areas, and for the 1st cycle of the Portuguese primary education system, whose Curriculum Guidelines explicitly state the crosscurricular nature of the approach. This allows the development of Computational Thinking and Project Based Learning in a multidisciplinary and curricula based approach.

Governmental initiatives to introduce programming and robotics in the Portuguese primary schools are close to the idea of development of Computational Thinking through Project Based Learning in a multidisciplinary approach. One important dimension is the connection between the activities and the curriculum. The Ministry of Education launched the project “Introduction to Programming in the 1st Cycle of Basic Education” (IP1CEB) aimed at developing Computational Thinking, digital literacy and transversal skills (Figueiredo & Torres, 2015). This pilot initiative ran from 2015/16 until 16/17, including primary school students from 3rd and 4th grade (9 to 10 years old). The initiative “Probótica - Programing and Robotics in Basic Education” followed in 2017/18, including primary education (up until 9th grade) (Pedro et al., 2017). However, in Portugal, the work for the development of algorithmic or computational thinking in preschool education is less expressive and there is still the need to support teachers and researchers in developing the area.

# CONCLUSION

## Suggestions for How to Integrate Algorithmic Thinking Skills into Preschool Education

Preschool children can be engaged in many age-appropriate activities through play. And play can facilitate the integration of algorithmic thinking into preschool learning activities. Algorithmic thinking improves children's problem-solving skills and helps them learn how to break down a whole process to facilitate the progression according to their goals. Since many learning processes need us to make progress step by step, we can integrate algorithmic thinking into many learning activities at preschool level. Algorithmic and computational thinking, as seen in the previous sections of this review, are not only related to computer science, and programming. These skills are used in a wide set of areas, whenever someone needs to tackle a new problem: he or she can understand the problem, evaluate how to solve it, choose the best strategies, decompose the problem in smaller sub-problems, and solve them step-by-step. In this view, algorithmic thinking can be used, and taught, also in early education, everytime children address a new problem or situation.

Teachers are one of the most crucial elements affecting the performances of children. Therefore, their intervention mostly determines the flow of the learning activities. While engaging children in the learning activities, narration, imitation and drama activities are of essential importance.

For example, while teaching the importance of brushing teeth and how to brush teeth, we can make use of algorithmic thinking and employ narration, simulation and drama. The teacher uses a puppet and makes it act as if it has a toothache. The teacher asks children ``Oh! What is wrong with the puppet? Do you want to ask him/her?" A volunteer asks (e.g.) "Are you alright? Do you feel bad?" Teacher makes the puppet talk "I have got a toothache." Teacher lets children talk, and give advice to the puppet. Then they agree that brushing teeth is important and necessary. The puppet says "But, I don't know how to brush my teeth." Then children specify the steps of the teeth brushing process. Then they can draw the pictures of the steps (each child draws only one step of the process not to waste time). They can show the steps to the puppet and the teacher makes the puppet follow the instructions.

Talking about sequences, in the early years, students are supported to understand sequenced events, patterns, and designing solutions (Blannin & Symons, 2019). So, drawing something that happens in sequence - as stated in the previous example - could be used to help algorithmic thinking children's development. Moreover, drawings could be also used in a different way, not only related to sequence based activities. Blannin and Symons (2019), took as an example the drawing of all combinations of sandwich that one could make for an excursion. A similar activity could be outlined, for example, also using the ring pyramid game, designed for early years education.

Also constructing something, with construction bricks or wooden blocks, can help the development of various skills, including algorithmic and computational thinking. Here we provide an example originally written by Resnick (2007):

Two children might start playing with wooden blocks; over time, they build a collection of towers. A classmate sees the towers and starts pushing his toy car between them. But the towers are too close together, so the children start moving the towers further apart to make room for the cars. In the process, one of the towers falls down. After a brief argument over who was at fault, they start talking about how to build a taller and stronger tower [...] In going through this process, kindergarten students develop and refine their abilities [...] they learn to develop their own ideas, try them out, test the boundaries, experiment with alternatives, get input from others – and, perhaps most significantly, generate new ideas based on their experiences.

During this process children use multiple skills, and doing that they learn. Because they deal with problems, and they try to figure out how to solve it in the best way, proceeding in small steps, making decisions and planning steps, trying to find out errors and bugs and assessing their actions according to the experience, they are also using algorithmic thinking. Furthermore, we can notice how using physical objects can both help in motor skills, as well in supporting the engagement and the interest in the activities.

Another facilitator is including “action” into the learning activities. When we let children move around, walk and run during the activities, they will be more engaged, have fun and not be distracted. For example, designating a parkour consisting of three different games (maths, art and sports) developing fine and gross motor skills of children can also make children stick to the activity and learn more effectively. Children can also race with each other. While doing this, children are told about the aim of each game through narration and in this way, the whole game makes sense for them.

Furthermore, several digital devices and systems have been developed as tools to support children's education, and many of them can also help in the algorithmic thinking learning process. As an example, various early education robots (e.g. Makeblock mTiny, Bee Bot and Blue Bot, Cubetto, ...) can be used. These appliances can support the development of many important skills, including the ability to reduce a problem, to proceed step-by-step, to debug an error and so on. Educational robots work as facilitators, and as objects that can attract the children's attention and interest and stimulate their engagement. As an example, robots can be programmed to move onto a grid, or in a space, according to a given story or a given goal. Doing activities like that, children can develop ordinary didactic skills as well as visuomotor and proprioception skills and algorithmic competences.

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